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Scientific Development vs. Political Strategy: NASA’s Commitment to Science Following the First Moon Landing

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Scientific Development vs. Political Strategy: NASA’s Commitment to Science Following the First Moon Landing

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By Sean Van Buskirk

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Abstract

This work looks at the scientific program of NASA during the Space Race. (1961- 1975) During this period of the Cold War, NASA shifted it role from a political asset of the United States strategy to an agency of scientific discovery. This was not a smooth transition due to political opinions on the wastefulness and role of NASA. Many politicians, citizens and even scientists had doubts about the scientific potential of NASA’s manned missions to the Moon. Despite the power politics, the administrators at NASA were able to break out of the political arena and create a balanced program where science became the driving force. From Apollo 11, where only a tiny science instrument kit was deployed, to Skylab, a space station that showed off NASA’s scientific potential. Unfortunately, NASA was unable to fully slip out of its political chains and was dragged back into the Cold War when it was tasked with meeting up with Russian cosmonauts in orbit. This work argues that due to pressure from outside forces, NASA had to modify, broaden, and sometimes eliminate its scientific agenda depending on the stage and politics of the Cold War.

I show within this work that, as mission planning progressed, NASA administrators and scientists pushed to increase the science with every mission. From Apollo 11, where only a tiny science instrument kit was deployed, to Skylab, a space station that showed off NASA’s scientific potential. Using mission reports and memos from within the agency, NASA pursued the policy of science-based missions, even when outside forces conspired to slow or even stop the agency’s agenda. This work contributes to the discussion of history of science and technology during the Cold War as well as adding to discourse of diplomatic history as seen in the chapter on the Apollo-Soyuz test project.

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Introduction: Connections of History and Science

How does science progress? This question is on the mind of many who step in a lab and perform scientific inquiry. It is also on the minds of those who chronicle and analyze the progress of science. Positivists see scientists as adding to the "stockpile" of science.[1] Positivist historians of science did not look at the context in which these "great heroes" conducted their scientific efforts. NASA scientists, to positivists, would not be influenced by the politics of the Cold War.

However, in 1962, Thomas Kuhn disassembled this notion of sequestered scientists sitting in their labs, oblivious to the outside world. In his work, *The Structure of Scientific Revolutions*, Kuhn stated that the historian of science can look at smaller non-revolutionary topics of scientific research and how they related to their time.[2] Kuhn uses the example of Aristotle. How did Aristotle relate to those around him? Kuhn states that we should not ask how Aristotle related to modern scientific theory.[3] Kuhn believes that looking at how new scientific thinking in the context of its time allows historians to see a shift of normal science, or dominate scientific thinking, to extraordinary science, seen as the buildup of anomalies against normal science. This "paradigm shift" in thinking led social historians to go further and question the relationships between scientists and power politics. The social historians of science during the 1960's found the heroes of science were steeped in the political power relations of their time, not just fiddling with their experiments.[4] They insisted the conflict of ideas is really between the

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[1] Joyce Appleby, Lynn Hunt and Margaret Jacob, *Telling the Truth About History* (New York: W.W. Norton and Company, 1994), 167, Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962), 2.
[2] Kuhn, *Scientific Revolutions,* 6-7.
[3] Ibid., 3.
[4] Appleby et al., *Telling the Truth About History*, 172.

people that hold them.[5] In this conflict is where scientific revolutions and changes in thought reside. These social historians portrayed ideas that explain why a nation would involve itself in space exploration.

The narrative of why a nation decides to go to space has been filtered through many lenses over the decades since the first rocket launch. At first "Lumpers," as Stephen J Pyne calls them, declared the space age as an extension of the European practice of exploration and colonization.[6] Lumper historians like William Goetzmann stated that space endeavors fit the mold of earlier exploration.[7] However, Pyne marks a split from this line of thought in the 1960's, the same time Kuhn was developing his paradigm shift. "Splitters" theorized that space exploration diverged from Goetzmann's second great age of discovery into its own distinct age.[8] This group places space exploration in its own category with exploration of Antarctica and the deep oceans, places where humans cannot exist without help.

Although historians of space exploration situated spaceflight fit on the timeline of human exploration, none of the lumpers or splitters dealt with how nations justified sending humans to space. Roger D. Launius, former chief historian at NASA, identified five themes that the social historians of the 1960's and 1970's used to justify large scale space exploration agenda. These include human destiny and survival; geopolitical and national pride and prestige; national security and military applications; economic competitiveness and scientific discovery and understanding. Identification of these themes by modern social historians was a break from the

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[5] John G. Mcevoy, "Modernism, Postmodernism and the Historiography of Science," *Historical Studies in the Physical and Biological Sciences* 37 (March 2007): 401.

[6] Stephen J. Pyne, "Seeking Newer Worlds: A Historical Context for Space Exploration" in *Critical Issues in the History of Spaceflight*, ed. Steven J. Dick and Roger D. Launius (Washington D.C.: NASA Office of External Relations, History Division, 2006), 11.

[7] Ibid., 11

[8] Ibid., 13

traditional thinking that heroes of science were smarter and more creative than everyone else.[9] As seen in the changing ideas in the history of science as a whole, agents of space exploration from the top down were affected by their time. These social historians eventually broadened these themes to fit four categories: political, social, technological, and cultural reasons for explorations of space.[10] Historians now relate space exploration to the context of the Cold War, diplomatic history and the history of science and technology.

This broader Cold War context mixed with United States relations with the Soviet Union and NASA's need to push science internally is where the heart of my work lies. I argue that due to pressure from outside forces, NASA had to modify, broaden, and sometimes completely scrap its scientific agenda depending on the stage and politics of the Cold War. NASA personnel and scientists were not shielded from the power politics and relations of the Cold War as the positivist historians might have claimed. On the contrary, NASA personnel and scientists drove change within the agency's scientific program. While engineering objectives remained first and foremost on many minds looking at the program, these people pushed to make sure science was included as much as possible. At many points during the Apollo Program, NASA was an agent of and in control of their program objectives. At other points, it was beholden to the politics of their time. In the end, despite the pressure of Cold War politics, the agency maintained and completed a successful scientific program.

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[9] Roger D. Launius, "Compelling Rationales for Spaceflight?" in *Critical Issues in the History of Spaceflight*, ed. Steven J. Dick and Roger D. Launius (Washington D.C.: NASA Office of External Relations, History Division, 2006), 44, Appleby et al., *Telling the Truth About History*, 172.

[10] Asif A. Siddiqui, "American Space History: Legacies, Questions, and Opportunities for Future Research" in *Critical Issues in the History of Spaceflight*, ed. Steven J. Dick and Roger D. Launius (Washington D.C.: NASA Office of External Relations, History Division, 2006), 458-459.

Chapter 1:1961-1969: Science Takes a Backseat

I: The Role of Science in the US Space Program

With the launch of Sputnik in 1957 and Yuri Gagarin's first flight in April 1961, the USSR firmly took the lead in the emerging Space Race with the United States. Prior to John F. Kennedy's challenge to the Nation in May 1961, NASA had still not conceptualized the science-related goals of its infant Moon landing program. However, the president received many reports from his science advisory committee. In January 1961, Jerome Wiesner, chairman of the president's committee, submitted a report to Kennedy outlining specific and important areas in the field of space science. Wiesner and his team recommended scientific objectives should have a prominent place in the planning of space goals and missions, wide participation by scientists should be encouraged, the program needed adequate financial support, and wisdom and foresight was necessary in the selection of science mission and scientists.[1] Outside of the government, the Space Science Board of the National Academy of Sciences, an organization founded in 1863 to serve as science consultants to the United States government, was NASA's chief scientific advisor.[2] In early 1969, the board published a paper entitled "Man's role in the National Space Program" in which it proposed that the goal of the space program should be scientific exploration but recognized that non-technical factors were necessary for national public acceptance. Yet declaring that the nation would go to the Moon just for scientific reasons had limited appeal. Divisions along these lines existed within the scientific community itself. Lunar

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[1] "Report to the President-Elect of the Ad Hoc Committee on Space," January 10, 1961, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*: *Volume 1: Organizing for Exploration*, John M. Logsdon, ed. (Washington: NASA History Office, 1995), 421.

[2] William David Compton, *Where No Man Has Gone Before: A History of NASA's Apollo Lunar Expeditions* (Mineola: Dover Publications, 2010), 5.

science was not as practiced as space science.[3] The majority of scientists focusing on space-based science not only studied the Moon, but they also studied all other celestial bodies in our solar system. Those in the scientific community who called themselves space scientists felt threatened by an endeavor to explore the Moon. Many feared Congress, to fund the Moon landing program and by extension lunar science, would slash funding for non-Apollo related projects.[4] This fear would prevail through much of the 1960s. The operational motif of NASA during the 1960s up until the first Moon landing revolved around the idea that scientific endeavors will naturally develop in the process of landing a man in the moon.

In February 1961, the House Committee on Science and Astronautics held hearings in which NASA informed Congress of its plans. George Low, chief of Manned Space Flight, described Apollo to the committee as an Earth orbiting laboratory and a program in which a flight around the Moon could be achieved, eventually leading to a landing.[5] Other administrators outlined objectives for the Mercury and Gemini programs which served as lead up and training for Apollo. However, during the hearing, on April 12, the Russian cosmonaut Yuri Gagarin became the first man ever to launch into space. This shocked the nation, and Congress responded to the news. The committee's chairman, Rep. Overton Brooks (D-LA), stated very seriously "my objective, and this is speaking individually, is to beat the Russians." Robert Seamans, associate administrator of NASA, told the committee that to achieve that objective, they would need to accelerate the program and that would need to coincide with considerable infusion of money from Congress. President Kennedy agreed and asked for an increase of more than $125 million

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[3] Ibid., 8.

[4] Ibid.

[5] Courtney G. Brooks, James M. Grimwood, Loyd S. Swenson Jr. *Chariots for Apollo,* (Mineola: Dover Publications, 2009), 24-25.

over the $1.11 billion that President Eisenhower earmarked in fiscal 1961.[6] This increase was submitted to Congress officially and also publicly through President Kennedy's challenge to the nation to land a man on the Moon by the end of the decade. However, as NASA continued to learn throughout the decade, increased funding increased pressure for results in engineering endeavors, not scientific discovery. Therefore, the agency had to follow the Cold War objective of beating the Russians first. Everything else was secondary. Following Kennedy's challenge, NASA got to work shaping the program that would put a man on the Moon. On May 8, 1961, the agency submitted its "Recommendation for National Space Program," also known as the Apollo Charter inside NASA. The charter delineated the reasoning for undertaking space projects: scientific knowledge, military value, improve commercial or civilian projects, and national prestige.[7] The charter highlighted the first and foremost of the agency's goals:

> Major successes, such as orbiting a man as the Soviets have just done, lend national prestige even though scientific, commercial, or military value of the undertaking may by ordering standards be marginal or economically unjustified.[8]

Again, officials at NASA understood that establishing science a cornerstone and major hallmark of their program would not allow them to gain the support to accomplish Kennedy's goal by 1969. NASA Administrator James Webb, however, was one of the champions for elevating science to a significant place in the program. In a memo to NASA program offices on July 5, 1961, Webb encouraged NASA personnel to facilitate the process of feedback in order to

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[6] Ibid., 25.

[7] "Recommendation for our National Space Program: Changes, Policies, and Goals," May 8, 1961, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*: *Volume 1: Organizing for Exploration*, John M. Logsdon, editor, (Washington: NASA History Office, 1995), 443.

[8] Ibid., 444.

improve "spinoffs" of the agency's programs.[9] Webb felt that if the employees of NASA could be open with their ideas, the agency could create new knowledge and technology which in turn could justify spending. NASA's administrators committed themselves then to ideas first as a defense for spending on scientific spinoffs, not committing money for increasing scientific objectives for science's sake. This way of allocating funding provides a major indication that internally, NASA officials saw the importance and need of a science-based program. As evidenced by the Webb memo, and throughout the decade, NASA supported many non-obvious [subtle but effective?] techniques of adding science to their manned spaceflight program. Yet this unwillingness to push science publicly led to a backlash from NASA's few supporters in the science community.

There was not unanimous excitement following Kennedy's historic challenge to beat the Russians to the Moon. Many of the skeptics came from the scientific community who feared emphasis on a lunar landing program would not advance or could possibly damage scientific discoveries in other areas of space science. Those who were already feeling the sting of a lunar program worked for NASA's unmanned space program. By late 1960, the increased focus and allocation of funds for manned spaceflight reduced or eliminated work on more sophisticated unmanned satellites that would be entirely science based.[10] Things got worse in the 1960s for those working in the unmanned program. Following Kennedy's challenge, NASA Deputy Director Hugh L. Dryden told the Senate Space Committee that Apollo planners would need data from the unmanned Ranger probes for information about the lunar surface.[11] Congress agreed

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[9] "Memo to NASA Program Offices, HQ, Directors, NASA Centers and Installations," July 5, 1961, in *Exploring the Unknown: Selected Documents in the History of U.S. Civil Space Program: Volume II: External Relationships*, John M. Logsdon, ed.r (Washington D.C.: NASA History Office, 1996), 494-495.

[10] Roger, E. Bilstein, *Orders of Magnitude: A History of the NACA and NASA, 1915-1990* (Washington D.C.: NASA Office of Management, 1989), 82.

[11] Compton, *Where No Man Has Gone Before*, 17.

and told the Jet Propulsion Laboratory, the NASA field center in California that serves as the hub for construction and research of unmanned probes, to comply with anything Apollo needed. This caused sour feelings within the community of scientists working at JPL because NASA managers moved in and changed Ranger's specifications. They removed existing experiments that scientists worked on for years and outfitted the probe with equipment to help Apollo. It infuriated the scientists even further to learn that the information from the new equipment ended up coming back too late and did not affect the construction of the Lunar Module, the vehicle that separated from the command module and landed on the Moon. This case is an example of some NASA administrators not respecting departments committed to science due to financial and public pressure. The scales of engineering versus science in the unmanned flight community weighed heavy on the side of science. Early manned flight had yet to push science directives as mission driving decisions.

This atmosphere of interference in scientific matters explains why many scientists were not onboard for going to the Moon. Many scientists, especially those in academia, enjoyed the privilege of not being told what to investigate.[12] They saw it as a perk of their profession to investigate scientific questions and problems of their choice. When NASA recruited these scientists, the objectives of the scientists and the objectives of the agency did not always fit together. This became evident to those scientists working within the Office of Manned Space Flight (OMSF). When the OMSF, the engineering division of NASA responsible for determining how to accomplish getting to and landing on the Moon, began requesting specific scientific

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[12] Ibid., 19.

experiments and inquiry to be worked on for the Apollo lunar landings, many scientists resolutely refused.

However, despite many scientists' feelings toward the OMSF, the engineering office did not always dictate how the science should operate and be conducted. In March 1962, the OMSF worked with the Space Science Steering Committee to suggest scientific tasks that could be performed by astronauts on future missions. The committee formed a working group chaired by Charles B. Sonett of the Lunar and Planetary Program office and included members from OMSF and Office of Space Sciences (OSS).[13] Homer Newell oversaw the OSS, and he attempted to run the office along guidelines that would best serve the scientific community under his direction. He allowed scientists under the OSS to pursue any experiment they thought was worthwhile. Newell felt that "pure science experiments will provide the engineering answers for Apollo."[14] OSS explained engineering guidelines to the Sonett committee, and they were left to decide what the scientific priorities where for a manned Moon landing. They concluded that the priorities of Apollo science should include measurements, qualitative observations, experiments on samples recovered from the Moon, and placing instruments on the lunar surface.[15] The committee also expressed concern about the training and scientific background of astronauts (this will be explored further in Chapter 2). This was the first time that science (OSS) and Apollo engineering (OMSF) started working closely together.

To unify the goals and conclusions of the OMSF and OSS, a working group replaced ad hoc committees in both organizations in September 1962.[16] Eugene Shoemaker, a geologist and

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[13] Ibid., 20.
[14] Ibid., 19.
[15] Ibid., 21.
[16] Ibid., 21.

scientist serving on the unmanned Ranger program, became the head of the group. The group ensured that each office met each other's needs. The group also notified the outside science community of NASA's scientific objectives to appear more transparent and quell concerns. As one of Shoemaker's first priorities, he asked the Manned Spacecraft Center, in Houston, Texas facility that trained astronauts and was the home of mission control, to instruct astronauts in the field of geology. Max Faget, director of Engineering and Development at MSC, agreed and wrote a letter to Bob Gilruth, head of MSC, who approved the idea.[17] On July 30, 1963, NASA reorganized Shoemaker's group into the Manned Space Science Division. It kept its same responsibilities but could carry them out at a higher administrative level.[18] Both Eugene Shoemaker and Max Faget are examples of scientists Kuhn wrote about, not content to allow the powers above them direct their scientific future. They engaged in the power politics of NASA in order to direct the agency's approach to science.

NASA also looked outside of its offices for advice on scientific priorities. In Summer 1962, a conference sponsored by NASA and the National Academy of Sciences published *A Review of Space Research*.[19] Those in attendance concluded that the important scientific tasks for the program should include observing scientific phenomena, collection of samples, and installation of monitoring equipment. It seemed that by the early 1960s, the scientific community was on the same page regarding what NASA should be doing in the field of science during the journey to landing a man on the Moon. Now they have to convince others.

II: United States Government versus Scientists

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[17] Ibid., 22.

[18] Ibid., 23.

[19] Brooks et al, *Chariots for Apollo,* 125-126.

By the end of 1962, the United States government was at odds with NASA over the space agency's immediate goals how to achieve them before the USSR. In November 1962, President Kennedy met with NASA Administrator James Webb to discuss how the program should be shaped. Shortly before this meeting, the director of the Bureau of the Budget, David E. Bell, sent a memo to the president about how Webb was set to move funds from Apollo to other departments. Bell expressed fear of NASA becoming "a one program agency," but he felt the landing was so urgent that funds should not be removed from it for other scientific endeavors.[20] Webb felt that while the Apollo lunar landing had the highest priority, a balanced program needed to have a place in mission planning and execution.[21] Webb argued that "a broad based space science program provides necessary support to the achievement of manned spaceflight leading to the lunar landing."[22] Webb would champion science throughout his tenure as administrator of NASA. Kennedy agreed with his budget director and believed that too much time was being spent on the precursory Mercury and Gemini programs, as well as time and money being utilized for scientific development. The president expressed his real feelings about the space program plainly:

> Now this may not change anything about that schedule, but at least we ought to be clear, otherwise we shouldn't be spending this kind of money because I'm not that interested in space. And the second point is the fact that the Soviet Union has made this a test of the system. So that's why we're doing it.[23]

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[20] "Director, Bureau of the Budget, Memo for the President, Space activity of the U.S. Government," November 13, 1962, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*: *Volume 1: Organizing for Exploration*, 457.

[21] Brooks et al, *Chariots for Apollo*, 110-111

[22] "James E. Webb, NASA Administrator to the President," November 30, 1962, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*: *Volume 1: Organizing for Exploration* , 463.

[23] "A Historic Meeting of the White House on Human Spaceflight," NASA History Office, Last modified November 5, 2002, accessed January 20,2017, https://history.nasa.gov/JFK-Webbconv/pages/backgnd.html#intrest.

The president saw the space race with the Russians as a show of strength and did not have a personal stake in seeing NASA preform the role of scientific discovery and exploration. To Kennedy, “the system” was an engineering objective of landing on the Moon before the Soviet Union. Webb assured the president that the manned landing would happen but advised against cancellations or curtailing science to push funds into Apollo.

Along with President Kennedy letting his private feelings be known to NASA officials, the space agency’s problems compounded in 1963 when Webb asked the Senate Committee on Aeronautical and Space Science, the body that voted on the budget for NASA, for a 54% increase in spending.[24] This amounted to a $2.012 billion increase, which allowed for a 50% increase in spending on science. The chairman of the committee, Senator Clinton P. Anderson (D-NM) felt that the requested increase in budget allocated for science needed investigation and consultation with prominent scientists in the space fields.[25] Philip Abelson, editor of *Science* magazine, argued that science would be better served by spending the money allocated for Apollo on unmanned missions instead.[26] Other scientists felt angry that NASA was pulling young talent from worthwhile research to work on the space program. Non-scientists such as President Dwight Eisenhower chimed in and stated that he thought the program did not justify the tax burden and could be invested in domestic programs. Following the complaints of scientists and others over the way NASA ran its scientific program, the committee did not grant the full requested increase but, decided to cut it by 10%, mostly in the area of science. NASA attempted to broaden the agency’s objectives too soon without significant results in areas where it received money. This is one of the main driving reasons why Mercury, Gemini and early

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[24] Compton, *Where No Man Has Gone Before*, 9.
[25] Ibid., 10-11.
[26] Ibid., 9-10.

Apollo were light on science. NASA, in an attempt to shift to a scientific discovery agency too quickly, risked losing financial backing. The agency retreated to engineering goals that could have more positive press and prestige than pursuing science-based objectives. Administrative changes in 1963 reflected this withdrawal.

Science took another hit in 1963 when the NASA Administrator brought George Mueller in to reorganize and run certain offices in NASA. The administrator hired Mueller to oversee NASA's three field centers: Marshall Space Flight Center (MSFC), Kennedy Space Center (KSC), and the Manned Spacecraft Center (MSC).[27] He brought all three field centers under the OMSF. Mueller also created the Manned Spaceflight Experiment Board to review all experiments for manned mission to space. Mueller wanted to ensure scientific experiment components were compatible with the spacecraft without interfering with mission objectives or schedules. He created the board to counter disruptions in the production of spacecraft due to constant changing of experiments and spacecraft specification. By doing so, Mueller wanted the landing to come first and if experiments could not keep up with spacecraft production schedules, they would be left behind. Despite the strides scientists made in the planning of missions, they again would have to take a back seat to engineering challenges and priorities.

Budget setbacks and administrative shakeups aside, Apollo mission plans began to take shape in 1963. During this year, NASA headquarters and its contractors drafted the "Apollo Systems Specification Book."[28] The aim of the book was to lay out the technical details, objectives of the program, and program requirements. Because of the early phase of planning, many pages, in what became known as the "headquarters bible," were marked "To Be

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[27] Ibid., 24-25.

[28] Brooks et al, *Chariots for Apollo*, 121.

Determined.” But one thing stands out in the book: the suggestion that exploration of the moon was not limited to one single mission.[29] Apollo could return for several, undefined missions. In late 1963 to mid-1964, NASA’s science teams highlighted the five fundamental areas of scientific research to focus on:

> Studies of the Lunar Lithosphere, the solid Moon itself, its chemical and physical constitution, and the implications this should have for its origins in history.
>
> Investigation of the gravitational and magnetic fields and forces around the Moon, including experiments for the possible detection of gravitation waves.
>
> Considerations of particles like solar protons and cosmic radiation, together with their effect on the lunar gravitational field and magnetosphere.
>
> Establishment of astronomical observatories on the Moon.
>
> Studies of proto-organic matter, including possibilities for exobiology.[30]

With the direction of scientific objectives hinted at, the teams of scientists at NASA and external contractors began to design experiments and work with NASA engineers and planners to implement them on lunar landing missions. The next item NASA worked on to help nurture science in the space program was to acquire funding from Congress for a laboratory to conduct experiments on returning astronauts and samples arriving from the lunar surface, but this would open a new battleground in which NASA had to defend its pursuit of conducting science in space.

III: NASA’s Fiscal Decline After 1965.

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[29] National Aeronautics and Space Administration, “Apollo Systems Specification Book,” OMSF Directive M-D M8000.001, May 2,1963: pg. 1-1, 1-2, 2-1, 2-2.

[30] Willis B. Foster to Director, Program Review and Resources Management, “Submission for 1964 President’s Annual Report,” (October 30, 1964): as quoted in Brooks et al, *Chariots for Apollo*, 126.

By early 1966, MSC had planned on a $6.5 million facility to house and study samples returned from the Moon.[31] Fears of contamination by unknown diseases that could potentially be brought back by astronauts led planners to add a quarantine facility to the lab. This meant that NASA had to ask for an increase to $9.1 million to construct and staff the Lunar Receiving Lab. However, by 1966 the landscape of NASA's budget had changed. President Lyndon Johnson had tightened the nation's purse strings and devoted more of his budget to domestic reforms and war in Southeast Asia. NASA was not immune to changes in political dynamics of the nation during the mid to late 1960s, and later 1970s. When James Webb went before the House Committee on Science and Aeronautics, there was pushback, and the committee requested further hearings to discuss the necessity and scope of the lab.[32] The OMSF and the Public Health Service provided testimony as to why the lab was essential. OMSF representatives stated that requirements from the scientific community—opinions that the subcommittee took seriously when it came to judging NASA—could be satisfied by the planned lab. The Public Health Service, armed with a letter of agreement from the Surgeon General, declared the lab necessary to prevent contamination to the earth by unknown pathogens possibly residing in space or the lunar surface.[33] However, when George Low, MSC's director and William Lilly, Apollo Control Director went before the subcommittee, several members had not read the OMSF and PHS's reports.[34] Congressman Donald Rumsfeld (R-IL) accused NASA of using the lab as a way to secure funding for future expenditures and scolded the organization for not using existing facilities.[35] NASA officials were unable to convince the subcommittee of the necessity of the lab,

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[31] Compton, *Where No Man Has Gone Before*, 48.

[32] Ibid., 48-49.

[33] House Committee on Science and Astronautics, 1967 NASA Authorization, Hearings before the Subcommittee on Manned Space Flight on H.R. 12718,8912, pt. 2, March 1, 1966, pg. 417-21.

[34] Compton, *Where No Man Has Gone Before*, 48-49.

[35] House Committee on Science and Astronautics, 1967 NASA Authorization, pg. 476.

and appropriations were struck from the 1966 bill. Desperate, NASA created a board to survey existing facilities.[36] The board found that no facility contained the requirements NASA needed. Officials from NASA returned to the subcommittee with their survey and the requested funds were added back to the bill, but NASA took a lashing publicly and financially before the ink on the appropriations bill was dry. Congressman James Fulton (R-PA), who felt back-contamination was a non-issue, accused the survey team of being predisposed by NASA higher-ups to choose Houston as the site of the new lab and disputed the centralization of the facility's proposed operations. "We simply have no facts on which to build a practical foundation and lab," he pronounced.[37] Fulton's objections must have held weight because the House Appropriations Committee slashed NASA's construction funds by $26.5 million, which included the new lunar lab, and the committee told the space agency to keep to the necessary minimum for specialized facilities. NASA budget problems would not end in 1966. In the appropriations for fiscal year 1967, congress cut its budget by $44 million.[38] This signaled a new era of restrained spending for NASA; space funding falling below $5 billion for the first time since 1963. Things did not improve for NASA due to a devastating fire that caused the agency to slow its plans and shook governmental and public confidence in the administration's operations.

IV: The Fire

While scientific efforts for Apollo were beginning to gain some speed, a disaster put the entire program on hold and caused NASA officials to become more cautious. The first manned

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[36] Compton, *Where No Man Has Gone Before*, 50.

[37] "4.9 billion is voted for NASA by House," *New York Times*, May 5,1966.

[38] Compton, *Where No Man Has Gone Before*, 50-51.

Apollo mission after the completion of the Gemini Program was AS-204, known later as Apollo 1. Apollo 1's objective was to verify and assess the crew/spacecraft operations and performance of the Apollo Command/Service Module (CSM) while in an orbit that would have lasted 14 days. However, technical issues with the spacecraft plagued NASA. The crew was unhappy, as were Apollo Project managers. During a test in January 1967, a fire broke out that killed astronauts Gus Grissom, Ed White, and Roger Chaffee. An investigation by NASA found major defects in workmanship and faults in management of the entire space program.[39]

NASA spent the summer of 1967 fixing problems with its spacecraft and improving management of the program. The half-year stall of the lunar landing program allowed other areas to catch up and recover, including science. The Science and Applications Directorate at the MSC was created to further quell scientists' remaining accusations and complaints that NASA was not doing enough to nurture science.[40] The directorate's creation allowed the Lunar Receiving Lab to be given more priority and autonomy. The Apollo 1 fire allowed NASA to take a step back and reassess its program.

With the changes to the CM completed in August 1967, planning for the first launch since the fire culminated in a manned Apollo mission in November of the same year. Apollo 4 was an unmanned "all-up" launch, in which every part (CSM and a dummy LM) went into orbit.[41] Because Apollo 1 would have been the 4th Apollo launch, planners maintained the naming scheme for the rest of the Apollo program. With the successful mission of Apollo 4, NASA had returned to the space race and was on its way to the Moon.

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[39] Brooks et al, *Chariots for Apollo*, 219-220.

[40] Compton, *Where No Man Has Gone Before*, 109.

[41] Gene Kranz, *Failure Is Not an Option: Mission Control from Mercury to Apollo 13 and Beyond*, (New York: Simon and Schuster, 2000), 209-211.

V: Apollo 11 Scientific Planning

Mission planning for the first manned lunar landing began in 1966. In a document presented at the Apollo Lunar Landing Symposium held at MSC, NASA outlined design priorities for the first landing. Science, however, was not included in NASA's list of considerations or priorities.[42] Despite it not being openly highlighted, NASA and its science teams worked on developing as many science experiments as it could in hopes that at least one would be included on the first flight.[43] This approach to planning science continued from the 1961 Webb memo of "ideas first" to justify spending.[44] NASA administrators believed if the ideas were good enough and thoroughly justifiable, they could be included on flights. As flights took place regularly following the recovery from the fire, scientific activities were limited to observations and rudimentary medical and biological experiments.[45] Training for lunar surface studies were limited to anything that could be easily done in a bulky pressure suit.

Notwithstanding these limitations, experiments were finally decided upon to accompany the first landing. In February 1966, NASA planners chose the Apollo Lunar Surface Experiment Package (ALSEP), a group of experiments that astronauts deployed and left on the Moon that sent data back to earth many years after the landing. One plus of this package that kept its viability in NASA's planning was that the experiments included in the package changed and evolved from mission to mission. (The ALSEP will be further discussed in the following

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[42] Manned Spacecraft Center, "Major Considerations in the Design of the First Lunar Landing Mission,"Presented at the First Lunar Landing Symposium: Proceedings and Compilation of Papers, Houston, Texas, June 25-27, 1966.

[43] Brooks et al, *Chariots for Apollo*, 203.

[44] Logsdon, *Exploring the Unknown: Volume II*, 494-495.

[45] Ibid., 260-61.

chapters.) Regardless of the selection of the experiments package, NASA began to experience problems in the training of using the package.

In 1967, problems between the astronauts and the experiments began to arise, and NASA officials were forced back into a debate over how much science should be present on the first lunar landing. Simulations of astronauts training with the ALSEP and lunar sample gathering showed that the explorers had problems deploying the experiments in a timely manner.[46] NASA planners had the mission planned down to the minute and any deviation could cost the agency money or be dangerous to the astronauts themselves. To add to NASA's list of engineering problems, batteries to power the experiments added an exorbitant amount of weight to the LM. This led planners to think about a less complicated scientific package or activity. Finally, in June 1968, George Mueller and George Low organized and oversaw simulations of scientific instrument deployment so they could evaluate and make recommendations to the mission planners. Following the demonstration by Astronauts Harrison Schmitt and Don L. Lind, Low outlined what the priorities for the first extra vehicular activity (EVA) should be:

1: Sample lunar surface
2: Inspect and photo the Lander
3: Gather 1 box of lunar soil
4: Partial ALSEP[47]

Low also advocated for the elimination of any geological investigation while on the lunar surface. Mueller and Low brought their recommendations to Sam Phillips, the Apollo Program director at NASA Headquarters, who discussed the potential changes in mission planning with

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[46] Compton, *Where No Man Has Gone Before*, 115.

[47] Leroy E. Day to MSC, Attn: MGR, ASPO, "ALSEP Deployment Demonstration," August 22, 1968; MSC, "Lunar Missions Review," August 27, 1968.

the chairman of the Science and Technology Advisory Committee. They agreed on a new EVA plan. Instead of a 26 hour stay on the surface with a two-man EVA, the committee concluded a 20 hour stay with a single person EVA of 2-2.5 hours would be sufficient.[48] The proposed plan also eliminated geologic exploration, a television antenna that did not have to be deployed manually by the astronauts, and all science experiments on the surface. The committee cited that the new plan increased safety margin for the LM propulsion system, increased the time for maintenance in case of emergency, simplified the training program for the mission by freeing up 180 hours of training time. The NASA headquarters committee and officials at MSC agreed on the new plan, except Wilmot Hess, the head of the Science and Applications Directorate at MSC. Hess protested the new plan and argued that it would not serve lunar science and hurt NASA's credibility with scientists.[49] He proposed an open-ended EVA lasting up to 3 hours if everything went well, as well as carrying all science experiments.[50] Phillips brought Hess's contingency EVA plan to MSC, which approved a compromise between the two new plans: a partial ALSEP, renamed the Early Apollo Surface Experiments Package (EASEP), photography of lunar geology, and sample collection by two astronauts. NASA headquarters approved the revised plan shortly after. Without Hess's protests, science would have been entirely eliminated from the first manned lunar landing. This episode also shows the willingness of NASA administrators to keep discussion of science priorities active. It would have been easier and safer to execute the simpler plan, but mission planners kept viable the idea of a balanced mission consisting of both science and engineering.

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[48] Compton, *Where No Man Has Gone Before*, 116.

[49] Ibid., 116-18.

[50] Wilmot N. Hess to Mgr., Apollo Spacecraft Program (MSC), "Changings in Mission G Plans," September 4, 1968.

In the months prior to the Apollo 11 mission, astronauts Neil Armstrong and Edwin "Buzz" Aldrin experienced difficulty in the course of their training for collecting samples and making geological observations.[51] The two astronauts trained for their experiment deployment and collection portion of the mission on a linoleum floor at the MSC. In a discussion following their return from the Moon, the two astronauts described this portion of their scientific training as "useless."[52] After Armstrong complained about his inability to pick up samples or manipulate tools with his large gloves, engineers treated one of the astronaut's gloves with silicone. The treated glove gathered samples better, and headquarters approved the change. However, NASA scientists objected to the change fretting that the silicone had the potential of contaminating the samples, but George Low refused to reconsider, and the silicone gloves remained. Armstrong also expressed concern about collecting quality samples and making scientifically significant observations while traversing the lunar surface. Armstrong was a test pilot and not a professional scientist or geologist; he felt underqualified for the scientific portion of the mission. He and Aldrin shared similar impressions following their flight that the geology field trips to the Grand Canyon did not help them in their lunar traversals due to "lack of realism," and, correctly predicted that future flights would use their information to make more productive geological surveys.[53] MSC geologist Elbert King told the astronauts that anything they described or collected would be significant because they would be the first people to do it.[54] Armstrong and Aldrin got their chance when they lifted off from KSC on July 16, 1969 and became the first humans to land on the Moon on July 24th.

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[51] Brooks et al, *Chariots for Apollo*, 323-24.
[52] Robert Godwin, *Apollo 11- The NASA Mission Reports*, (Ontario: Apogee Books, 1991), 151.
[53] Ibid.,
[54] Compton, *Where No Man Has Gone Before*, 140-41.

VI: Apollo 11 and Scientific Community Reaction

During their EVA on the lunar surface, Astronauts Armstrong and Aldrin achieved a series of firsts: first steps on the Moon, first conversation with a world leader on the lunar surface, first television broadcast from another world, and first lunar samples disturbed by human hands. Scientists who watched the EVA unfold were pleasantly surprised to find the two astronauts acting like scientists. The two men debated what type of rocks they found. Armstrong even left the camera's vision, a departure from the flight plan, to look at some unusual rocks that grabbed his attention.[55] However, during the bulk sample collection operations, the crew found that, due to the way the LM had landed, they worked mostly in darkness.[56] Mission planners did not consider the LM would block the sun and cast a large shadow over the work area. The astronauts grabbed the EASEP from its LM stowage spot and deployed the Lunar Ranging Retroreflector (LRRR) and the passive seismograph with little difficulty.[57] The LRRR consisted of cubes of silica that reflected laser beams from earth to determine precise Earth-Moon distances, motion of the Moon's center of mass, lunar radius, and earth geophysical information. The passive seismograph measured meteoroid impacts and moonquakes to determine the makeup of the Moon's interior. After a short 2 hour and 31 minutes, the crewmen reentered the LM and mankind's first scientific exploration of another world was completed. Back on Earth, many in the scientific community were ecstatic, with one scientist characterizing the result as "instant science."[58]

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[55] Ibid., 145.

[56] Godwin, *Apollo 11*, 81.

[57] Brooks et al, *Chariots for Apollo*, 348, 394.

[58] Victor Cohn, "Old Moon Game Taunts Players," *Washington Post*, September 21, 1969.

However, not all were impressed or happy with NASA's scientific efforts following the first landing. Outrage came about after the naming of Apollo 13 and 14's crews: not one scientist-astronaut was selected. To add to scientist's fears, following Apollo 11, resignations quickly came from many NASA officials in key scientific positions in the agency and scientists themselves. Donald U. Wise, deputy in the Lunar Exploration Office, Dr. Elbert King, scientist-astronauts F. Curtis Michel, and Wilmot Hess all resigned around August 1969.[59] All but Hess expressed some displeasure with the state of science in the program. Eugene Shoemaker, a strong advocate of science on Apollo also left and stated that everything the Apollo 11 astronauts completed could have been done sooner and cheaper by unmanned spacecraft.[60] The press jumped at the chance to air more soundbites by NASA's disgruntled former scientists. The press quoted Elbert King as saying, "there's not enough sympathy with or understanding of scientific objectives at the higher levels of NASA."[61] Bob Gilruth questioned the nature of the scientist-NASA relationships and George Mueller, never one to mince words, cautioned that scientists were impatient and could not see what was possible.[62] Mueller promised "adjustments" to future mission planning to show NASA's true commitment to the sciences.

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[59] Compton, *Where No Man Has Gone Before*, 168.

[60] Eugene Shoemaker, "Space-Where Now, and Why?" *Engineering and Science* 33 (1969): 9-12.

[61] "Scientists Vs. NASA," unsigned editorial in the *New York Times*, August 12, 1969.

[62] Mueller to Gilruth, September 3, 1969.

Chapter 2: Apollo 12, 13 and 14: Transition into Science Based Missions

I: Science Training and Scientist-Astronauts

While the planning for the first manned lunar landing did not involve significant science training outside the simple tasks Neil Armstrong, Buzz Aldrin and Michael Collins experienced, NASA realized the subsequent missions required astronauts to transform into scientists. This new plan to train astronauts, who were usually test-pilots, opened discussion within NASA to a debate what kind of astronauts should be sent for scientifically heavy missions. The debate boiled down to NASA having to decide whether to send test pilots trained in science or send scientists who were trained to fly spacecraft. By 1962, astronauts in the Mercury and Gemini programs were primarily instructed in meteorology, astronomy, and the physics of earth's upper atmosphere with instruction on how to make scientific observations from orbit.[1] In the same year, a NASA working group reviewed astronaut training and concluded it would be easier to train test pilot astronauts in as much science as possible than to train a scientist-astronaut in space flight piloting.[2] The former group would be "astronaut-observers," directed by "ground-scientists" that instructed the astronauts what to do and what to look for from mission control on Earth.[3] In September 1962, Eugene Shoemaker, a geologist and instructor for the astronauts, urged MSC to allow him and his team to train the astronauts in geology.[4] Max Faget, director of engineering and development at MSC, wrote a letter to Robert Gilruth and advocated for

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[1] National Aeronautics and Space Council, *U.S. Aeronautics and Space Activities, January 1 to December 31, 1959, Report to Congress from the President of the United States*, (Washington D.C., February 22, 1960), 9, https://history.nasa.gov/presrep1959.pdf; National Aeronautics and Space Council, *U.S. Aeronautics and Space Activities, January 1 to December 31, 1960, Report to Congress for the President of the United States,* (Washington D.C., January 18, 1961), 8, https://history.nasa.gov/presrep1960.pdf.

[2] Compton, *Where No Man Has Gone Before*, 57.

[3] Ibid., 58.

[4] Ibid., 22.

Shoemaker's idea. With both MSC and scientists backing the idea, Gilruth agreed, and geology was added to astronaut scientific training schedule. However, some in the scientific community remained unhappy with what they saw as lack of respect for the importance of science in the Apollo Program due to the earlier decision to send test pilots instead of scientists to the Moon. During the 1963 NASA budget hearing in Congress recounted in Chapter 1, Philip Abelson told the committee that the "already small scientific value of Apollo would be further lessened unless a scientist went on the landings."[5] As others in the scientific community piled on this opinion, NASA made strides in 1964 to answer scientists' concerns surrounding astronaut training and the question of scientist-astronauts.

NASA used the criticism from the scientific community to make improvements to its scientific training plans for astronauts who would eventually walk on the Moon. According to an annual report by President Johnson's National Aeronautics and Space Council delivered to Congress, 1964 marked the year that NASA increased emphasis on training in geology, minerology, and petrology.[6] Astronaut training schedule became more comprehensive, including 20-week series [so one 20-week series?] of lectures, briefings, and field trips.[7] Instructors guided astronauts through a one semester college course in land forms, land forming geologic processes, minerals and their origins, and reading topographic and geologic mapping. NASA sent astronauts with instructors for geologic training in the Grand Canyon, Big Bend in west Texas, and to the volcano fields of Arizona and New Mexico. This change in astronaut science preparation reflected the agency's new goals of ensuring astronauts be able to investigate and interpret

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[5] Ibid., 9-10.

[6] Petrology is the study of the origin, distribution, and structure of rocks; National Aeronautics and Space Council, *U.S. Aeronautics and Space Activities, January 1 to December 31, 1964, Report to Congress from the President of the United States*, (Washington DC, January 27, 1965), 15, https://history.nasa.gov/presrep1964.pdf.

[7] Compton, *Where No Man Has Gone Before*, 62-63.

terrain and forms that could resemble what they would eventually find traversing the surface of the Moon. During training for Apollo 14, a scientist reiterated the importance of the astronauts taking their training seriously as it related to their job on the Moon:

> You two could kick off a whole new renaissance of the Moon. It's our belief that Cone was carved out of the Moon's surface more than four billion years ago. One hell of a meteoric impact. By the way the crater is gouged, there's every chance it ripped away rocks from maybe three hundred feet down and that these rocks were tossed about along the crater rim. If that's what you bring back with you, then we'll be able to study material that came into existence about the same time the planets and Moons of the solar system were still forming out of dust and gas, contracting into the worlds we see today throughout the system. You two will be, in every sense of the word, traveling back in time. You'll see what we're after. No mistake about that.[8]

Many scientists, like the one quoted above, were frothing at the mouth waiting for results and samples from the lunar surface. All of NASA's improvements to astronaut science training in 1964 aimed at maximizing the science-side of the short stay on the Moon. Agency officials thus hoped to quiet the scientific community's doubts about the Apollo program. However, there proved no silencing critics until NASA promised to send a scientist to the Moon.

In October 1964, NASA confused many onlookers with the announcement that the agency was looking for another batch of astronauts, but no longer required that candidates be test pilots.[9] Behind the scenes, NASA specifically looked for applicants with scientific backgrounds. Internally, MSC officials and representatives from the National Academy of Sciences (NAS) met in February 1964 to discuss requirements for scientist-astronauts.[10] The academy defined scientist qualifications, and MSC agreed to set physical and psychological requirements. The NAS mandated that an accepted applicant should have a doctorate in medicine, engineering, or

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[8] Shepard and Slayton, *Moon Shot*, 313.

[9] Brooks, *Chariots for Apollo*, 179.

[10] NASC, *U.S. Aeronautics, and Space Activities: 1964,* 16; Compton, *Where No Man Has Gone Before*, 65-66.

natural sciences, specifically geology, and geophysics, and those accepted would be assigned to the Air Force for one year of flight training. NASA received 1000 suitable applicants and chose six to be the new crop of scientist-astronauts. Then in 1965, NASA finally unveiled its new group of astronauts to the public. Every time NASA presented its new class of astronauts, the press placed a catchy nickname on the group. For the first group was branded "The Mercury Seven," then came "The New Nine," followed by "The Fourteen." This new group became "The Scientists." The Scientists astronaut group included Owen K. Garriott, Edward G. Gibson, Duane E. Graveline, Joseph P. Kerwin, F. Curtis Michel, and Harrison H. Schmitt.[11] Each boasted impressive credentials in their respective scientific based fields. Garriott held a doctoral degree in electrical engineering from Stanford University. Gibson earned a Ph.D. in engineering with a minor in physics from the California Institute of Technology. Duane Graveline specialized in Aerospace medicine after earning his Doctor of Medicine from University of Vermont College of Medicine. Joseph Kerwin served as a naval flight surgeon from 1958 following his completion of a Doctor of Medicine degree from Northwestern Medical School. Curtis Michel graduated from California Institute of Technology with a degree in physics. Finally, Harrison Schmitt completed his Ph.D. in Geology in 1964 after attending Harvard University. Only Garriott, Graveline, Kerwin and Michel had previous military experience before joining NASA in 1965. With this new group of astronauts, NASA attempted to make good on its promise to bring a scientist onboard as an active participant on lunar landing missions, but it would be a long road before any of "The Scientists" would get their chance to fly.

NASA's changing attitudes toward science became evident throughout the 1960's through to the number of internal studies it authorized on the training programs for astronauts. In

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[11] Brooks, *Chariots for Apollo*, 179.

the fall of 1965, the Manned Space Science Study Division commissioned a study that examined the extent of astronaut training as it pertained to science. The study deemed the training program again short on science.[12] The study's investigators recommended that more scientist-astronauts could improve the program by harnessing more resources to train other astronauts. The study also recommended that scientist-astronauts should be encouraged to keep up their independent research activity thus remaining active members of the scientific community. This would include one full day per week of participating in discussions and seminars with one week per month where scientist-astronauts could leave their astronaut duties to be fully immersed in their research.[13] The recommendations rubbed some of the other astronauts the wrong way. Concerns that scientist-astronauts could be "part-time" were summed up later by astronaut Eugene Cernan:

> [Some] of those guys came in figuring, "I'll write my textbooks and my thesis and teach [university courses] and I'll come by twice a week and be an astronaut.' Well, that didn't work… We are devoting our lives to this whole thing, and you couldn't devote anything less, I don't care what your discipline was.[14]

The sentiment was shared by NASA officials who received the report, but nothing came of the sections recommending increases in the recruitment of scientist-astronauts. NASA officials like Deke Slayton, head of the astronaut office, believed "No one would benefit from a dead geologist [and his colleague in the LM] on the Moon."[15] Scientist-astronauts had to prove they could fly and become competent pilots before being entrusted to go to the Moon. While NASA officials admitted the science in their programs was lacking, the agency was not yet committed to have a scientist-astronaut as the primary actor in a mission, e.g., mission commander. Instead, in

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[12] Compton, *Where No Man Has Gone Before*, 70-71.

[13] Ibid.

[14] Ibid., 71

[15] Ibid.

the 1960s, NASA used its scientist-astronauts as tools to bring science training to the level they wanted, and to win over critics in the scientific community.

II: Apollo 12 – Transition to Lunar Exploration

Apollo 11 showed that NASA and the United States could fly men to the Moon and return them safely to the Earth. Following the celebrated landing, NASA moved into the next phase of its Apollo program. Apollo 12 would mark the transition from the lunar landing phase to the lunar exploration phase of the program.[16] According to the president's report to Congress, the main feature of this transition was a reduction in launch rate from 2 months to 4-month intervals. The president's Space Task Group explained this new gap between missions placed a greater emphasis on lunar science and to reduce costs. These phases are important to look at because they show NASA had a plan to ramp up science as more missions were completed. As NASA became more adept at flying science-based missions, the flights' parameters became more and more focused on science. Also, Apollo 12 set out to prove possible a pinpoint landing in a predetermined landing area. If the crew could succeed at this, the future outlook for scientific exploration would be greatly enhanced.[17] Apollo 11 had trouble at their original landing site due to large boulders blocking suitable spots to land. Armstrong and Aldrin placed the lander down where they could and ended up many miles away from their original target. NASA officials hoped that if Apollo 12 accomplished a precise landing, sites with unique properties for scientific exploration would open up. Apollo 12's target was the Surveyor 3 probe that crash-landed on the lunar surface in April 1967. Commander Charles "Pete" Conrad and Lunar Module Pilot Alan L.

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[16] National Aeronautics and Space Council, *Aeronautics and Space Report of the President: 1969* (Washington D.C., January 1970), 8-9, https://history.nasa.gov/presrep1969.pdf.

[17] Ibid.

Bean managed to land 600 feet, walking distance, from the probe.[18] They achieved a pinpoint landing, and scientific exploration of the Moon became more targeted, allowing scientists to answer specific questions about the lunar surface by choosing where to land. Apollo 12 also marked the point in the program where science was upgraded to a primary mission objective.[19] This was a significant step for science, which previously took a back seat to engineering objectives. Science was now one of the cornerstones for mission planning and execution.

Planning for Apollo 12 marked the debut of the Apollo Lunar Surface Experiment Package (ALSEP). The ALSEP was the full version of the EASEP first flown on Apollo 11, which allowed more advanced experiments to be carried on each Apollo flight, as well as long term data gathering once the astronauts departed for the Earth. The complete ALSEP consisted of eight experiments, five to six of which would be carried per mission, a central station that served as the data transmission and communication hub, and a SNAP-27 Radioisotope Thermoelectric Generator that provided power to the experiments and central station.[20] The nature of the ALSEP's customizability allowed scientists and mission planners to pick and choose experiments differently for each mission depending on the particular scientific goals. Apollo 12's ALSEP contained six experiments for its maiden voyage to the Moon. A Passive Seismometer Experiment (PSE) detected "Moonquakes" to study the lunar subsurface structure.[21] The Lunar Surface Magnetometer (LSM) measured the Moon's magnetic field to

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[18] Samuel Lawrence, "Pinpoint Landing on the Ocean of Storms," (Arizona State University: School of Earth &Space Exploration, Lunar Reconnaissance Orbiter Camera, March 6, 2012), accessed August 26, 2017, http://lroc.sese.asu.edu/posts/401.

[19] Richard W. Orloff, *Apollo By the Numbers: A Statistical Reference* (Washington D.C.: NASA History Division, 2000), 341.

[20] National Aeronautics and Space Council, *Report to the Congress from the President of the United States: 1966,* (Washington D.C.: January 1967), 22-23, https://history.nasa.gov/presrep1966.pdf.

[21] National Aeronautics and Space Administration, "Apollo 12 Press Kit," in *Apollo 12: The NASA Mission Reports*, Robert Godwin, ed., (Ontario: Apogee Books, 1999), 8-9.

determine the electrical properties of the subsurface and the interaction between solar plasma and the lunar surface.[22] The Solar Wind Spectrometer (SWS) studied the solar wind and its effect on the environment of Moon's exterior.[23] NASA scientists designed the Suprathermal Ion Detector Experiment (SIDE) to measure the properties of positive ions present in the lunar environment. The experiment worked with the LSM to provide data on plasma interaction and to determine electric potential of the surface of the Moon. Coupled with the SIDE, the Cold Cathode Ion Gauge (CCIG) measured the presence of the lunar atmosphere.[24] Finally the Lunar Dust Detector (LDD) measured lunar dust accumulation and was expanded to include particle, radiation and temperature studies on Apollo 14 and 15.[25] All of the experiments contributed to knowledge of the Earth and the Moon by determining the state and structure of lunar interior, composition of the lunar surface, the processes that modified it, and the evolutionary sequences that led to the Moon's composition.[26]

However, going to the Moon to recover Surveyor 3 and set up the ALSEP would not be the Apollo 12 astronauts' only job. While on the surface, astronauts Conrad and Bean participated in two EVAs that lasted three and a half hours each, almost twice the total time Aldrin and Armstrong spent traversing the lunar surface. While astronauts spent the first EVA unloading and deploying the ALSEP, the second EVA consisted of the astronauts completing a lunar field geology experiment.[27] With real time geology advisors from Earth communicating

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[22] Ibid.
[23] Ibid.
[24] Ibid.
[25] Ibid; National Aeronautics and Space Administration, "Apollo 14 Press Kit," in *Apollo 14: The NASA Mission Reports*, Robert Godwin, ed., (Ontario: Apogee Books, 2000), 20-24; National Aeronautics and Space Administration, "Apollo 15 Press Kit," in *Apollo 15: The NASA Mission Reports*, Robert Godwin, ed., (Ontario: Apogee Books, 2001), 23.
[26] NASA, "Apollo 12 Press Kit," in Godwin, *Apollo* 15?? 18.
[27] National Aeronautics and Space Administration, "Apollo 12 Mission Operation Report," in *Apollo 12: The NASA Mission Reports,* 82-91.

directly through headsets worn by the astronauts, Conrad, and Bean documented samples, collected a deep core sample using a specialized hand drill, and dug a trench to document the erosion effects of the lunar surface.

In lunar orbit, Command Module Pilot Richard F. Gordon, Jr. had plenty to keep him busy as well. Alongside photographing of future Apollo landing sites, he took multispectral photographs of the lunar surface that allowed scientists to see variation for geologic mapping and study its reflective nature, and correlate photographs with returned samples.[28] Between experiments, the astronauts on the surface also took photos with a camera more advanced than those brought on Apollo 11, as well as attempted to set up a color television camera to broadcast high quality pictures. However, a mistake by astronaut Bean, who pointed the camera directly at the sun, destroyed a tube in the camera.[29] Despite this, Apollo 12's lunar surface and lunar orbit stay was a massive scientific success; reams of data poured in from the experiments operating on the Moon. One highlight that excited scientists was that the PSE recorded astronaut footfalls in real time as well. It recorded the commander rolling a grapefruit-sized rock down the wall of a crater.[30] Apollo 12 proved that the science could be collected in space, and experiments could gather data from a celestial body a quarter of a million miles away.

III: Apollo 13 – Successful Failure

The third manned Moon landing, in 1970, aimed to be the most ambitious one yet. NASA was getting the hang of sending men to the Moon, and the public was beginning to see the

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[28] National Aeronautics and Space Administration National Space Science Data Center, Apollo 12 lunar Photography, July 1970, National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Maryland, pg. 3, https://www.hq.nasa.gov/office/pao/History/alsj/a12/Apollo12LunPhotogNSSDC70-09.pdf.

[29] National Aeronautics and Space Administration, "Apollo 12 Mission Operation Report," in Godwin, *Apollo 12: the NASA Mission Reports*, 82-91.

[30] National Aeronautics and Space Administration, "Apollo 12 Post Flight Operation Report," in *Apollo 12: The NASA Mission Reports,* 127.

spectacle as routine. The mission planned to include two, four-hour long EVAs with an option to be extended to five hours each depending on astronaut condition and number of remaining consumables.[31] Apollo 13's ALSEP contained new instruments not flown on previous missions. The mission planned to deploy a PSE, which would become the second in a 3-point coverage net for seismometers, along with the PSE from Apollo 12 and eventual placement of a device on Apollo 14.[32] The Charged Particle Lunar Environment Experiment (CPLEE) aimed to measure the particle energies of protons and electron that reached the lunar surface from the Sun.[33] The Lunar Atmosphere Detector (LAD), also called the Cold Cathode Gauge Experiment (CCGE), amounted to a standalone version of Apollo 12's CCIG.[34] This experiment was never flown in an ALSEP configuration following this mission. Apollo 13's ALSEP also contained the Heat Flow Experiment (HFE) that tracked thermal measurements of the Moon's subsurface to determine the rate at which heat flowed out of the Moon.[35] This experiment promised to give scientists a better understanding of the thermal evolution of the Moon. These experiments, in conjunction with Apollo 12's ALSEP, could provide answers to questions about the Moon's physiology, evolution, and relationship to the Earth.

Apollo 13 mission planners also packed the EVAs with lunar surface activities not pertaining to ALSEP deployment. Two contingency samples of 2 pounds of materials were planned at the commencement of each EVA.[36] Planners prepared for 95 pounds of representative lunar materials, including core samples and fragments from the Fra Mauro Hills, the planned

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[31] National Aeronautics and Space Administration, "Apollo 13 Press Kit," in *Apollo 13: The NASA Mission Reports*, Robert Godwin, ed., (Ontario: Apogee Books, 2000), 17.

[32] Ibid.

[33] Ibid., 24.

[34] Ibid., 25.

[35] Ibid., 26.

[36] Ibid., 19.

landing spot for Apollo 13 lunar astronauts James Lovell and Fred Haise. The astronauts would perform geological surveys and take photography of small geological features that could not survive transportation.

While his colleagues explored the lunar surface, Jack Swigert was to conduct photographic studies from orbit as well as to investigate and document how water flowed in space following a water dump from the service module.[37] The command module pilot was also instructed to perform an experiment while in orbit: VHF Bistatic Radar Experiment. This experiment consisted of reflecting a VHF signal off the lunar surface back to an antenna on Earth.[38] By conducting this experiment, scientists could have used the data to determine the depth of lunar regolith layers, the soil that covers the solid rock on the surface of the Moon.

However, all the mission planning for Apollo 13 proved for naught due to an explosion in the spacecraft's oxygen tank 56 hours into the flight. All the systems in the command and service module had to be shut down to conserve power for the crew's return and the lunar module had to be used as a lifeboat. The astronauts powered the LM to the lowest levels possible to keep life support and communications operational during the return to Earth. At that point, the farthest thing from any person's mind at NASA was conducting science. However, routine procedures prior to Apollo 13's accident allowed for some science. Apollo 13 was the first time NASA began the established procedure of intentionally crashing the third stage of the Saturn V rocket, the S-IVB, into the lunar surface and measuring its effect on ALSEP instruments. When Apollo 13's S-IVB impacted the lunar surface, Apollo 12's PSE picked up the Moonquake.[39] Apollo

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[37] Ibid., 24.

[38] Ibid.

[39] National Aeronautics and Space Administration, "Apollo 13 Post-Launch Mission Report," in *Apollo 13: The NASA Mission Reports*, 83.

12's SIDE recorded a spike in ion counts after impact due to the increased temperatures and particles from impact were ejected 60 kilometers off the lunar surface and were ionized by sunlight.[40] Despite the "successful failure" of Apollo 13, the next Apollo program inherited many of the ideas for the mission

IV: Apollo 14 – Extending the Stay with New Tools

Despite Apollo 14 inheriting Apollo 13's mission objectives and landing site, NASA mission planners utilized the time allotted for the investigation of the accident to make Apollo 14 the most scientifically saturated mission to the Moon yet. This task was accomplished in part by increasing the time traversing the surface and changing the way astronauts transported and worked with samples while preforming their scientific tasks.

NASA mission planners maneuvered to keep Commander Alan B. Shepard, an original Mercury astronaut, and Lunar Module Pilot Edgar Mitchell on the lunar surface for a maximum of 35 hours, a full 15 hours longer than Apollo 11 stayed and 5 hours longer than Apollo 12.[41] EVAs for the two men were planned to be 4 and a half hours each with an increase to 5 hours allowed if the astronauts were physically up to the change. Due to this increased time on the surface of the Moon, NASA engineers developed a new piece of technology to aid the astronauts in equipment transportation and sample collection. The Modularized Equipment Transporter (MET) was a two-wheeled table used to hold cameras, science equipment and collected samples while working on the Moon.[42] The MET also highlighted the expanded partnership between NASA's engineering and science offices. No longer was the engineering side the primary focus,

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[40] Ibid.

[41] National Aeronautics and Space Administration, "Apollo 14 Pre-Mission Operation Report," in *Apollo 14: The NASA Mission Reports*, 63

[42] NASA, "Apollo 14 Press Kit," in *Apollo 14: The NASA Mission Reports*, 38.

both offices worked together on projects to ensure the success of mission goals. Astronauts were now no longer hindered by how many samples they could carry on their person. Due to the appearance of how the astronauts used the MET, the cart earned the nickname "the rickshaw, wheelbarrow and caddy cart."[43] Apollo 14 astronauts had the tools to stay on the surface longer and maximize the scientific potential of going to the Moon.

NASA scientists and planners customized the ALSEP for Apollo 14 to take advantage of the unique surface characteristics of the Fra Mauro Highlands. Along with a PSE, designers equipped the ALSEP with an Active Seismic Experiment (ASE) that consisted of 21 pyrotechnic "thumpers" and mortars.[44] The thumpers were charges that the crew laid down and detonated at 15-foot intervals in order to get a reading and data from the PSE. Like smashing a S-IVB into the surface, the thumpers would give scientists data on the Moon's subsurface structures. The crew deployed a mortar component of the ASE that contained four rocket projectiles that would be directed by mission control to launch and impact the surface once the crew left for Earth.[45] Along with a CPLEE originally flown on Apollo 13, the Apollo 14 ALSEP also carried a version of Apollo 11's LRRR.[46] Aside from the new experiments, the ALSEP also included the SIDE and CCIG experiments as well as a standalone version of the Solar Wind Composition Experiment.[47] Launched in February, 1971, Apollo 14's ALSEP took what worked on previous missions and added some novel experiments that explored the unique environment of its landing site.

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[43] Walter Froehlich, *Apollo 14: Science at Fra Mauro*, (Washington D.C.: United States Government Printing Office, 1971), 3.

[44] NASA, "Apollo 14 Press Kit," in *Apollo 14: The NASA Mission Reports,*, 20.

[45] Ibid.

[46] Ibid., 23-24.

[47] Ibid., 25.

Once the ALSEP was set up and activated, Apollo 14 astronauts had other experiments to attend to while exploring the Fra Mauro Highlands. While they worked and moved about the surface, the astronauts deployed a Lunar Portable Magnetometer (LPM) on the MET to measure variation in the Moon's magnetic field.[48] As on the Apollo 12 mission, astronauts dug a trench to test how lunar soil moved. This time, the crew completed the experiment to gather data on designs for future lunar vehicles and development for lunar shelters.[49]

The astronauts also participated in less serious experiments. Before the crew left the surface, Commander Shepard made a makeshift golf club by connecting a six-iron head to the handle of the sample extractor tool.[50] Shepard then revealed two gold balls and took several one-handed swings, but due to the bulky space suit he missed several times. When he finally connected, he exclaimed they went "miles and miles and miles" in the low lunar gravity. Mitchell also threw one of his lunar sample scoops like a javelin.

While his fellow astronauts were on the surface having the time of their lives, Command Module Pilot Stuart Roosa worked hard on his orbital science objectives. Roosa spent much of his time photographing candidate sites for future missions and observing his crew member's work on the surface. Roosa also had to complete the bistatic radar experiment originally planned for Apollo 13 and a s-band transponder test designed to pick up variation in lunar gravity.[51] When the surface crew rejoined their colleague in orbit, the astronauts completed several zero-gravity in-flight demonstrations for television cameras in the spacecraft. The crew test electrophoretic separation in zero-g by testing red and blue dyes, hemoglobin, and DNA to see if

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[48] Ibid., 24.

[49] Ibid., 25.

[50] Froehlich, *Science at Fra Mauro*, 10.

[51] NASA, "Apollo 14 Press Kit," in *Apollo 14: The NASA Mission Reports,*, 26.

preparation of materials in space could lead to the development of engineering ideas to make new vaccines on space stations.[52] The astronauts also tested heat transfer in weightless liquids and gases such as water, a sugar solution and carbon-dioxide gas. Following these in-flight demos, Shepard reflected on the usefulness of doing these experiments and the value of the space program:

> If, for example, these manufacturing processes turned out to be better in the space environment, or the vaccines, which are proposed to be developed on a weightless condition can be used effectively, then this type of operation in Skylab can become immediately beneficial to the people of the United States and the world.

He spoke to the detractors who accused the space program of wasting money and providing no benefit. He saw a paradigm shift that Kuhn theorized. A shift from normal science before the lunar landings to this "extraordinary science" being done. Shepard, who had seen the program from the beginning, knew the value of manned space flight as it pertained to science. Kuhn's theory about conflicting ideas leading to a shift in scientific discovery is evident in the space program's trajectory.

Apollo 14's mission revealed interesting data for scientists on Earth. When Apollo 14's S-IVB impacted the Moon, it was the first time the full network of PSEs recorded an event.[53] Upon return to Earth, scientists within NASA studied Apollo 14's command module windows to find information about the size and distribution of small micrometeoroid impacts.[54] Not all experiments went smoothly though. The ASE encountered many problems with the thumpers. Of the 21 thumpers deployed, 5 did not fire when commanded.[55] Due to the failed thumpers and

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[52] Ibid., 34-36.

[53] Froehlich, *Science at Fra Mauro*, 19.

[54] NASA, "Apollo 14 Pre-Mission Operation Report," in *Apollo 14: The NASA Mission Reports*, 70.

[55] National Aeronautics and Space Administration, "Apollo 14 Post-Mission Operation Report," in *Apollo 14: The NASA Mission Reports*, 102.

concern over the deployment of the mortar, mission control never fired the four rockets.[56] There were attempts to fire them in 1975, but the long dormancy caused the charges to fail.[57] NASA's planned it next forays to the Moon to be longer and more exciting from a scientific standpoint, especially with the inclusion of a new vehicle.

V: Life Science Reorganization

While NASA remained on track to rack up successful missions following the investigation into Apollo 13's accident, agency officials decided to look inward at its scientific program. In the spring of 1970, NASA asked the Space Science Board of the National Academy of Science to review the agency's life science program.[58] Following the inquiry and examination, the board recommended that if the agency combined several life sciences disciplines under a single office, they would become more effective.

As seen in Chapter 1 where engineering and science departments came under oversight of one office to facilitate communication and cooperation, NASA took the board's recommendation and created the NASA Director for Life Science position which oversaw the new NASA Life Science Office under the OMSF. The NASA Life Science Office included scientists who worked in the disciplines of biology, medicine, man-machine cooperation, human factors, and life support/protective systems. One of the first things the new office worked on was a new flight crew health stabilization program following Apollo 13's pre-flight exposure to measles-rubella.[59] The program kept crews in the process of training away from exposure from viruses and diseases

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[56] Ibid.

[57] Matthew Brzostowski and Adam Brzostowski, "Archiving the Apollo Active Seismic Data," *The Leading Edge* 28, no.4 (April 2009): 414-416.

[58] National Aeronautics and Space Council, *Aeronautics and Space Report of the President: 1971 Activities*, (Washington D.C.: March 1972), 17, https://history.nasa.gov/presrep1971.pdf.

[59] Ibid.

that could manifest in space.[60] In April 1971, the office discontinued the quarantine process for crews returning from the Moon.[61] Life science office researchers, by examining lunar samples, discovered the Moon was basically sterile with no hazard of back-contamination present. In 1972, the life sciences team headed up development of new lightweight, comfortable space suits for shuttle missions for long term use during missions.[62] By championing and pursuing its commitment to science, NASA created an office for scientific disciplines to work together and affect change on the space program.

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[60] Ibid.

[61] Ibid.

[62] National Aeronautics and Space Council, *Aeronautics and Space Report of the President: 1972 Activities*, (Washington D.C.: March 1973), 11, https://history.nasa.gov/presrep1972.pdf.

Chapter 3: Apollo 15, 16 and 17: Squeezing the Most Science Out of the Apollo Sponge

I: Budget Problems Eliminate Late Lunar Missions

1970 proved a rollercoaster of a year for NASA and its scientific exploration of Earth's Moon. The agency returned from near disaster following Apollo 13's accident with more scientifically heavy missions, and it prepared to go further with extended stay missions. However, the year ended on a down note when, due to the waning of public interest and shifting priorities in the US government, NASA announced cuts to several missions and a shift in focus going forward. A report the Bureau of the Budget prepared for President Richard M. Nixon, then just assuming office, signaled shifting winds for NASA. "Priorities of national interests have shifted, and this put space lower on the list. This caused less funding to be put aside for NASA and therefore less ability to perform missions," concluded the report.[1] Despite successful missions to the Moon, NASA scientists could not escape power politics. They were not free to tinker in their labs, sheltered from the greater Cold War occurring outside their offices and labs. Unmanned systems were less expensive for missions involving data collection, announced the report, and therefore should be the agency's new focus.[2] Finally, the Bureau of the Budget asked the question that was on the minds of many public and government officials following the first landing: why do we continue with manned missions?

> Reasons for proceeding other than competition include enhancing the national prestige, advancing the general technology, or simply faith that manned space flight will ultimately return benefits to mankind in ways now unknown and unforeseen. None of these secondary arguments can be quantified and are most difficult to support.[3]

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[1] "National Aeronautics and Space Administration: Highlight Summary," October 30, 1968, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program" Volume 1: Organizing for Exploration,* John M. Logsdon, ed., (Washington: NASA History Office, 1995), 495-497.

[2] Ibid.

[3] Ibid.

NASA was unable to sway the new administration into continued funding manned exploration of the Moon. Because the new Republican executive administration and Republican-controlled congress looked to cut some spending from the national budget, NASA recast plans for the remainder of Apollo and beyond.

On January 4, 1970, George Low canceled Apollo 20.[4] The remaining 7 missions (Apollo 13-17) would be stretched out to 1974, with 4 missions planned to fly in 1970-1971. Low announced the Apollo Applications Program, soon to be known as Skylab, would be flown before the final 3 lunar landings. Ten days later, Administrator Paine, following preliminary budget discussions, announced that Saturn V production would be suspended following the completion of the 15th booster. NASA allocated the final booster for Skylab. This second announcement also ended all talk of a Mars mission, because NASA no longer had a long-range heavy lift vehicle in development.

The final nail in the coffin of the Apollo program came in September 1970, following the decision to make significant cutbacks to save for future missions. Administrator Paine called a press conference to formally announce NASA's operating plan for fiscal 1971. Apollo 15-19 were cancelled, and the remaining missions were redesignated 14-17 and planned to occur at six-month intervals.[5] Following the completion of Apollo 17, three Skylab missions would be flown. Paine did not say it in so many words, but according to the 1970 President's Report on Space Activities, NASA expected the Apollo program to be completed by 1972.[6]

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[4] Compton, *Where No Man Has Gone Before*, 194-196.

[5] Ibid., 303.

[6] National Aeronautics and Space Council, *Aeronautics, and Space Report of the President Activities: 1970* (Washington D.C., January 1971), 10, https://history.nasa.gov/presrep1970.pdf.

Paine's final announcement drew many critics.[7] An editorial in the *New York Times*, which long had been opposed to NASA's prominence in the budget and the government, was scathing and called into question the agency's priorities for Apollo. "The budget's myopia which forced this… decision can only vindicate the critics who have insisted Apollo was motivated by purely prestige considerations, not scientific goals."[8] Lunar scientists became vocal about the decisions for cutbacks because many university scientists lost funding in the new fiscal plan. Harold Urey, a renowned chemist interested in lunar science following Apollo 11 wrote a piece for the *Washington Post* that highlighted much of the reaction from the scientific community:

> It cost us… one half of one percent of our gross production… Now we wish to finish a job which has been beautifully began. And we get stingy. Because of an additional cost of about 20 cents per year for each of us we drop two flights to the Moon recommended by scientific committees composed of men who personally profit from the expenditure little or not at all. How foolish and short sighted from the view of history can we be?[9]

One common idea was prevalent in everyone's criticisms of the budgetary decision: the remaining missions must maximize scientific potential. This became the mantra for the remainder of Project Apollo. Despite the way it came about, the budget crisis forced NASA to put its best scientific foot forward and brought the agency in step with its true goal: scientific exploration of the Moon. NASA's strategy for manned lunar missions now placed science fully in the driver's seat. Science objectives dictated many aspects of mission planning.

II: Apollo 15: Apollo Enters Its Final Phase

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[7] Thomas Paine resigned from his position as NASA administration on September 15, 1970.

[8] "Retreat from the Moon," *New York Times,* September 4, 1970.

[9] Harold C. Urey, "Untitled Article," *Washington Post*, September 17, 1970, quoted in William David Compton, *Where No Man Has Gone Before*: *A history of NASA's Apollo Lunar Expeditions* (Mineola: Dover Publications, 2010), 202.

As Apollo 12 marked a new phase for exploration of the Moon by NASA, Apollo 15 ushered in the final phase of men walking on the Moon in the 1970s. The highlights of this new phase, named the Apollo "J" missions, included longer stays on the Moon, enhanced mobility while on the lunar surface, and increased the amount of lunar and orbital science completed in the duration of each mission.[10] Apollo 15 mission planners allotted for a 67 hour stay on the lunar surface, double the length of time spent on the lunar surface by Apollo 14.[11] This increase in the time promised to be even more productive with the introduction of the Lunar Roving Vehicle. (LRV)

On August 4th, 1969, Bob Seamans wrote to Vice President Spiro Agnew arguing that Apollo astronauts needed additional mobility to traverse the Moon more effectively.[12] NASA contractors submitted designs, and Boeing won the contract to develop the new vehicle. The agency contracted Boeing to build 4 LRVs beginning in October 1969, but due to the budget cuts, only three were ultimately built. Between October 1969 and the Apollo 15 mission in August 1971, Boeing completed over 70 operational tests on the vehicle to make sure it was ready for its maiden voyage.[13] The LRV could operate for 78 hours per mission and driven in a radius of 6 miles from the LM in the event it stopped working.[14] This mission rule was put in place, so astronauts would not become stranded and would always be in walking distance for the lander. To transport the rover to the Moon, the LRV folded up tight to fit in quad 1 of the LM

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[10] National Aeronautics and Space Administration, "Apollo 15 Press Kit," in *Apollo 15: The NASA Mission Reports*,, 22.

[11] National Aeronautics and Space Administration, "Pre-mission Operation Report," in *Apollo 15, The NASA Mission Reports*, 126-127.

[12] "Robert C. Seamans, Jr., Secretary of the Air Force, to Honorable Spiro T. Agnew, Vice President," August 4, 1969, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*: *Volume 1: Organizing for Exploration*, John M. Logsdon, ed., (Washington: NASA History Office, 1995), 521.

[13] National Aeronautics and Space Administration, "Apollo 15 Press Kit," in *Apollo 15: The NASA Mission Reports*,, 54.

[14] Ibid., 45.

and was easily removed and set up by astronauts once on the lunar surface.[15] The rover also carried experiments on its platform. With the LRV, astronauts could travel farther from the LM and conduct science without being restrained by what previously was not feasible, and mission planners set loftier goals for scientific observation, experimentation, and discovery.

Mission planners chose the landing site for Apollo 15 based on its diverse terrain types and landscapes bundled together in a close area. The Apennine/Hadley area consisted of five distinct types of landforms.[16] An examination of the Apennine Mountain range could yield a collection of material ejected from the nearby Antolyen Craters. Scientists wanted samples from Hadley Rille to determine the origin of the rille itself. The Palus Putiedinis also intrigued scientists because it was a flat surface on the Moon, was younger than Apollo 11's landing site, and could shed light on recent Earth-Moon history. Finally, five kilometers north of Apollo 15's landing site sat large craters and hills made of volcanic domes. The cornucopia of land types around the Apollo 15 astronauts assured that scientific yield would be at a new high and had the potential of keeping scientists busy tabulating data for years.

Apollo 15's surface crew carried the most advanced scientific equipment the Apollo program had seen thus far. The crew's ALSEP boasted 7 experiments: PSE, SWS, SIDE, HFE, CCIG, LDP and a Lunar Surface Magnetometer, a new experiment in the program. The Lunar Surface Magnetometer (LSM) measured the Moon's magnetic field and detected fluctuation within the field.[17] In many ways, the astronauts on the lunar surface went back to basics. The astronauts preformed a stand-up EVA when they first arrived on the Moon. This comprised of an astronaut using the upper hatch of the LM to describe his first impressions of the surrounding

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[15] Ibid., 44.
[16] Ibid., 34-35.
[17] Ibid., 23.

landscape of the landing site.[18] This was an important addition to procedure because it gave scientists an idea of a detailed map due to orbital cameras only being able to have a resolution up to 20 meters.[19] The scientists and mission planners could only make a rough estimation of the terrain and features surrounding the landing site. The stand-up EVA would give a better picture and help mission planners cross off or add objectives based on what the astronauts saw around them. Following the stand-up EVA, the astronauts took time to sleep to be ready for the rest of the EVAS on the lunar surface, which like previous missions included ALSEP deployment, geological traverse, deep core samples, and a soil mechanics experiment as well as using the new LRV to go further and longer during EVAs.[20]

In orbit, the command module also contained new experiments that became standard for remining Apollo missions. Many of the new orbital experiments aimed at giving a full map of the lunar surface not previously seen. A Gamma Ray Spectrometer contained an extendable bloom that conducted x-ray and alpha-ray experiments on the light and dark sides of the Moon.[21] The X-Ray Fluorescence Experiment measured spikes in the x-ray levels caused by solar x-ray interactions with the surface of the Moon. The final new mapping experiment was an Alpha Particle Spectrometer. This experiment mapped the surface by looking at mono-electric alpha particles emitted from the surface. Orbital science duties also contained experiments completed on earlier flights including UV photography, Gegenschein Experiment, Bistatic Radar, and

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[18] National Aeronautics and Space Administration, "Apollo 15 Pre-Mission Operation Report," in *Apollo 15: The NASA Mission Reports*,, 126-127.

[19] National Aeronautics and Space Administration, "Stand-Up EVA," in *Apollo 15 Flight* Journal, Eric M. Jones and Ken Glover, eds., (Washington D.C.: NASA History Division, October 2014), 106:50:01, History.nasa.gov/alsj/a15/a15.seva.html.

[20] National Aeronautics and Space Administration, "Apollo 15 Pre-mission Operation Report," in *Apollo 15: The NASA Mission Reports*,, 127.

[21] National Aeronautics and Space Administration, "Apollo 15 Press Kit," in *Apollo 14: The NASA Mission Reports*,, 35-39.

Composite Casting Experiment.[22] The creation of the Scientific Instrument Module (SIM) on the CSM, allowed NASA space to store a metric and panoramic camera.[23] These cameras, when deployed, photographed the entire visible surface of the Moon from orbit. Recovery of the film also posed a challenge with cameras located outside of the command module. This required, an astronaut to conduct an EVA outside the craft during the return flight to Earth to recover the film. With more expansive experiments added to Apollo, NASA constantly searched for new procedures to maximize the scientific potential of the equipment and astronauts it sent to the Moon.

One change the CSM experienced was inclusion of a subsatellite released in orbit that contained 3 experiments, much like an ALSEP in orbit. The SIM continued to send data from orbit long after the astronauts returned to Earth.[24] The SIM's S-Band Transponder Experiment found data on the lunar gravity field from orbit. The Particle Shadows and Boundary Layer Experiments gathered information on the formation of earth's magnetosphere, interactions of plasmas with the Moon and physics of solar flares. The final SIM experiment, the Biaxial Fluxgate Magnetometer, helped scientists characterize the physical and electrical properties of the Moon.

Following the crew's return from the Moon, NASA scientists conducted experiments on the astronauts and spacecraft. As on Apollo 14, NASA scientists and engineers completed the Apollo Window Meteoroid Experiment.[25] The astronauts were subjected to total body

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[22] Ibid.
[23] Ibid.
[24] Ibid.
[25] Ibid.

spectrometry.[26] NASA scientist and medical personnel completed tests to detect changes in total body potassium, muscle mass and radiation in astronauts returning from the Moon. This experiment's designers hoped to shed light on the toll that long duration spaceflight took on the human body. The data from this experiment would impact future missions such as Skylab where astronauts would stay in space much longer in zero-gravity than a duration of a flight to the Moon.

Scientists around the world had an overwhelmingly positive reaction due to Apollo 15. This was mostly due in part to the discovery of a sample returned from the Moon that was named the "Apollo 15 Genesis Rock."[27] After being analyzed, scientists discovered the sample contained a piece of the original lunar crust formed shortly after the creation of the Moon. The genesis rock appeared the oldest rock returned on any Apollo mission. Scientists dated it to be 4.15 billion years or older. Along with the Genesis Rock, Apollo 15 returned a deep core sample that contained a record of the last billion years of the Sun's activity. Many commented on the abilities of the astronauts. Larry A. Haskin, vice chairman of the Lunar Sample Analysis Planning Team wrote to Bob Gilruth that "We felt comfortable and confident that the scientific aspects of the mission were in competent hands."[28] Scientists had much to be excited about with Apollo 15's work and the outlook on the final 2 Apollo missions.

III: Apollo 16: Peak of Orbital Science

Many of the previous Apollo missions had explored the darker areas of the Moon, thought to be once part of the ancient lunar sea. NASA's penultimate mission to the Moon, in

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[26] National Aeronautics and Space Administration, "Apollo 15 Post-Operation Mission Report," in in *Apollo 15, The NASA Mission Reports*, , 127.
[27] NASC, *1971 Activities*, 12.
[28] Compton, *Where No Man Has Gone Before*, 240-242.

April 1972, aimed to land in the Moon's southern highlands, known as the Descartes Highlands. Scientists thought these lighter areas of the Moon to be higher than the ancient lunar seas and to contain rock that covered 11.5% of the lunar surface.[29] NASA mission planners and scientists hoped recovery of samples from the Descartes Highlands would yield material that could represent more of the lunar surface than Apollo astronauts could cover. NASA mission planners knew they were running out of missions to the Moon and wanted to get as much material that represented as much of the Moon as possible.

One problem NASA astronauts on previous missions encountered was the disintegration of samples during recovery and return to earth. Sampling bags damaged lunar samples. Scientists complained that the outer 1/100th of an inch was valuable to study the radiation history of a sample and the existing sample bags wore that layer away. NASA engineers developed a new sampling bag with a padded interior to help protect thinner rocks.[30] The new bags were another way to maximize science potential as much as possible in the face of the end of the Apollo manned landing program.

Apollo 16's ALSEP contained a mix of experiments that had become standard and experiments that had not been flown since early Apollo missions. The PSE, LSM, and HFE were once again deployed. NASA scientists also sent an Active Seismic Experiment with Apollo 16 after the first unsuccessful attempt to fully deploy it on Apollo 14.[31] However, because the ASE's pitch sensor malfunctioned following the firing of three sets of explosives, the fourth set

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[29] Gene Simmons, *On the Moon with Apollo 16: A Guidebook to the Descartes Region* (Washington D.C.: United States Government Printing Office, 1972), 7.
[30] Ibid., 34.
[31] National Aeronautics and Space Administration, "Apollo 16 Press Kit," in *Apollo 16: The NASA Mission Reports*, Robert Godwin, ed., (Ontario: Apogee Books, 2002), 30-38.

never fired.[32] Of the twenty-two thumper charges, nineteen were fired on Apollo 16. NASA tried this experiment once more on Apollo 17.

More problems plagued Apollo 16's ALSEP package. During set-up of the second of the ALSEP's HFE probes, the cable snagged around Commander John Young's boot and separated the probe from the central station.[33] NASA technicians and astronauts felt a fix was feasible, but mission control decided the time-consuming repairs would be better used on other work. Mission control also feared the danger to other ALSEP experiments was too high to attempt to repair the HFE. While NASA grew adept at sending men to the Moon, no mission was perfectly executed because, as in scientific investigation and testing, human error always remained present.

Along with other surface experiments carried over from earlier missions such as the Portable Magnetometer, Solar Wind Composition Experiment, and conducting an investigation of surrounding lunar geology, Apollo 16 astronauts had new scientific equipment to deploy in the Descartes region.[34] The Soil Mechanics Device consisted of a penetrometer, a tool to test the strength of a material, specifically designed for lunar soil. When the astronauts forced the penetrometer core into the ground, it measured characteristics and mechanical properties of the lunar soil.[35] This experiment amounted to a more advanced version of the soil mechanics experiment from earlier Apollo missions. An experiment unique to Apollo 16, the Cosmic Ray Detector mounted on the LM's decent stage, measured changes in the mass and energy of cosmic rays and solar wind particles.[36] Astronauts completed the EVA's and removed the device from

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[32] National Aeronautics and Space Administration, "Apollo 16 Post-Mission Operation Report," in *Apollo 16: The NASA Mission Reports*, 135.

[33] Ibid., 127.

[34] NASA, "Apollo 16 Press Kit," in *Apollo 16: The NASA Mission Reports*,, 39, 41.

[35] Ibid., 39.

[36] Ibid., 43.

the exterior of the LM and returned it to Earth for analysis. The final new experiment had been previously done on the orbital side of Apollo missions. The astronauts set up a far ultraviolet camera and spectroscope at various points during their EVAs.[37] They pointed the camera at astrological objects such as star clouds, nebulae, galaxy clusters, intergalactic hydrogen, solar bow clouds, solar wind, and the atmospheres of the Moon and Earth. Upon completion of the EVAs, the astronauts removed the film cassette and returned it to Earth for scientists to pour over the negatives. Apollo 16's lunar surface science objectives offered a mix of old and new and showed NASA as willing to entertain new experiment ideas despite the mission being the penultimate flight for its lunar exploration program.

In terms of tracking NASA's commitment to science during the Apollo era, Apollo 16 orbital science objectives and experiments reflected a significantly greater commitment than on earlier Apollo missions. Of all the trips to the Moon done under the banner of Apollo, 16's mission holds the record for most done during the orbital portion of the mission.[38] While in orbit of the Moon, Command Module Pilot Ken Mattingly conducted the Laser Altimeter, S-Band Transponder Experiment, Gamma-Ray Spectrometer, Alpha-Particle Spectrometer, Orbital Mass Spectrometer, X-Ray Fluorescence Spectrometer, Bistatic Radar, used the metric and panoramic cameras, and deployed the subsatellite.[39]

During the flight from Earth to Moon, orbit around the Moon and return to the earth, the crew completed several experiments to investigate the characteristics of a space environment. Astronauts tested the response of microbes by measuring the effects of reduced oxygen pressure,

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[37] Ibid., 41.

[38] Ibid., 49.

[39] Simmons, *On the Moon with Apollo 16,* 7; NASA, "Apollo 16 Press Kit," in *Apollo 16: The NASA Mission Reports*,, 50-56.

vacuum zero-g, and ultraviolet irradiation on five strands of bacterial fungi and viruses.[40] The new Visual Light Flash Phenomenon Experiment had its roots in previous Apollo missions but was not realized until Apollo 16. During rest periods on previous missions, crewman reported that flashes of light penetrating their closed eyes.[41] On Apollo 16, planners set two rest periods aside to conduct the experiment. During these periods, two of the three astronauts wore eye shields, while the third wore the Apollo Light Flash Moving Emulsion Detector to measure the cosmic rays thought to cause the light flashes. The detector's plate would then be analyzed by scientists on earth post-flight. The astronauts also completed the Biostack Experiment which studied the effects of cosmic radiation on biomaterial.[42] The experiment composed of exposing material to high energy ions present in cosmic radiation. Scientists studied the results of this experiment because they hoped it would give an indication of how ions could pose a threat to man during long duration flights. In preparation for the Skylab flights, NASA also had Apollo 16 astronauts conduct operational tests and experiments on items that would be used in the upcoming space laboratory.[43] They tested food packages, the improved gas/water separator, and fecal collection bags. These results would help prepare NASA for its next stage of manned spaceflight.

On return to Earth, the astronaut's scientific tests continued. NASA scientists and medical personnel subjected them to a Bone Mineral Measurement Experiment that examined changes in human bone density due to changes in gravity impacting the human body.[44] The CM had the Window Meteoroid Experiment conducted on it to measure the effect of

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[40] Ibid., 56.
[41] Ibid., 57.
[42] Ibid.
[43] Ibid., 57-58.
[44] Ibid., 57.

micrometeoroids.[45] Finally, a special Moon rock was tested that underwent a unique voyage. A rock recovered from an earlier Apollo landing had its natural magnetism removed by NASA's team of scientists and was sent with the Apollo 16 astronauts back to the Moon.[46] The crew carried the rock on the voyage back and returned to Earth once again to see if the magnetism had returned during the course of its journey. NASA's penultimate flight squeezed every opportunity to conduct science throughout its mission.

Apollo 16 easily counted as a scientific success due to the number of experiments conducted and data received. During the three EVAs, the surface astronauts traveled 27 kilometers across the Descartes highlands and collected 213 pounds of representative material.[47] Data from experiments allowed scientists to build upon knowledge gained from previous missions and plan for Apollo's final landing.

IV: Apollo 17: NASA's Manned Landing Swan Song

In many ways, Apollo 17 in late 1972 culminated the work and perseverance of NASA scientists. One of the most notable achievements scientists earned on the final Moon landing was the opportunity of sending one of their own on the voyage. NASA selected geologist Harrison Schmitt as the Lunar Module Pilot on Apollo 17. While serving as an astronaut at NASA since 1965, he instructed Apollo on lunar navigation, geology, and feature recognition.[48] He also aggressively advocated integration of scientific activists in the lunar landing program. Someone

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[45] Ibid., 49.

[46] Simmons, *On the Moon with Apollo 16*, 33-34.

[47] NASA, "Apollo 16 Post-Mission Operation Report," in *Apollo 16: The NASA Mission Reports*,, 128,134.

[48] National Aeronautics and Space Administration, "Apollo 17 Press Kit," in *Apollo 17: The NASA Mission Reports*, Robert Godwin, ed., (Ontario: Apogee Books, 2002), 88.

who was a scientist first and astronaut second finally reached the Moon, only one of many firsts for the final landing on the Moon.

Mission planners and NASA science personnel long debated Apollo 17's landing site. The area of the Moon that finally won out was the Taurus-Littrow Mountain/Crater Range.[49] This area had the advantage of the presence of lunar highland material, the hills processed characteristic of volcanic structures, and the site had minimal overlap with Apollo 15 and 16 to maximize samples and data. To further prevent repetition in date collection, NASA Science and Applications Directorate allowed the Apollo 17 crew to see samples from previous missions and discuss what they should look for.[50] However, due to the unknowns about the landing site and surrounding area, scientists instructed the astronauts to "use their heads."[51]

As NASA's final trip to the lunar surface, Apollo 17's experiments included all new experiments developed for the cancelled Apollo 18 and 19 lunar flights.[52] The only returning equipment was the Heat Flow Experiment.[53] The first new ALSEP experiment was the Lunar Ejecta and Meteorites Experiment (LEAM).[54] This device measured the physical properties of primary and secondary particles that impacted the lunar surface. Designers fashioned together detector plates that tracked the pressure of the particles. The second ALSEP experiment was the Lunar Seismic Profiling Experiment.[55] (LSPE) This investigation replaced the PSE and ASE and brought the two experiments together in one package. After the crew left the surface, the

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[49] Ibid., 37-38.

[50] National Aeronautics and Space Administration, "Apollo 17 Technical Crew Debriefing," in *Apollo 17: The NASA Mission Reports*, 192.

[51] Gene Simmons, *On the Moon with Apollo 17: A Guidebook to Taurus-Littrow* (Washington D.C.: United States Government Printing Office, 1972), 21.

[52] NASC, *1971 Activities*, 14.

[53] NASA, "Apollo 17 Press Kit," in *Apollo 17: The NASA Mission Reports*,, 39.

[54] Ibid., 43.

[55] Ibid., 43-44.

explosive charge would detonate, and the experiment would transition into a PSE state until the remnants of the LM impacted the surface, at which point the device would be deactivated. The third ALSEP experiment was the Lunar Atmospheric Composition Experiment. (LACE), which studied measured components in the ambient lunar atmosphere.[56] The experiment sought to confirm the existence of gravity waves as predicted by Einstein's Theory of Relativity, as well as to gain insight into the Moon's interior structure.[57] However, due to a design error, the experiment proved unable to detect the waves scientist sought to corroborate. The ALSEP was not the only part of Apollo 17 mission to conduct new experiments.

Apollo 17 astronauts brought newer scientific hardware with them, outside of the ALSEP experiments, and these were tested during the course of their lunar exploration of Taurus—Littrow. The Traversal Gravimeter sat mounted on the LRV and traced the gravitation properties of the landing site and remote locations along the geologic travel route.[58] The scientists back on earth used this data to compare geologically similar areas of the earth-lunar relationship and shared history-struggling a bit to follow this. The Surface Electrical Properties Experiment consisted of a transmitter placed 100 meters from the LM and a receiving antenna mounted to the LRV.[59] By sending and receiving signals between the transmitter and receiver, scientists measured the electromagnetic energy transmission, absorption, and reflective characteristics of the lunar surface and subsurface. The final lunar surface experiment was a Lunar Neutron Probe.[60] This test consisted of a probe inserted into the core sample hole in order to measure neutron flux on the top two meters of the lunar soil. Researchers compared the probe's data to

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[56] Ibid., 46.
[57] Ibid., 46-47.
[58] Ibid.
[59] Ibid., 47-48.
[60] Ibid., 49-49.

isotopes in the core sample upon return to earth. As astronauts left the surface of the Moon for the final time, they conducted one final experiment, one technically continuing today. The crew left their science instruments and tools on the Moon from Apollo 17 and placed in such a way to be retrieved in a few decades after 1972.[61] Scientists hoped to return to the surface and recover various NASA tools and equipment to investigate how long-term exposure to the lunar surface and space environment impacted these objects. However, scientists could not have known the space program would not return in the planned time frame and the objects still await recovery.

For lunar orbital science, NASA scientists found the full potential of utilizing the SIM of the CSM. The Lunar Sounder Experiment beamed HF and VHF magnetic impulses toward the lunar surface in an effort to gain a geographic model of the lunar interior to 1.3 kilometers.[62] Scientists hoped the orbit of the SIM would yield the most detailed map of the Moon's interior to date. The SIM also contained an Infrared Scanning Radiometer. Previously, a temperature map of the Moon could only be done from earth. With the SIM, scientists located rock fields, crustal surface differences, volcanic activity, and fissures that emitted hot gasses.[63] The SIM also contained a Far UV-Spectrometer that helped scientists measure atomic composition, density, and scale height on the lunar surface. Finally, the SIM bay also contained a panoramic camera, mapping cameras and a laser altimeter.[64] The SIM on Apollo 17 allowed scientists to gain the clearest and most complete picture of the Moon to date.

Due to the high volume of orbital experiments, NASA mission planners ordered Apollo 17 to stay in lunar orbit two additional days following rendezvous operations between the surface

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[61] Ibid., 53-54.
[62] Ibid., 56-57.
[63] Ibid., 59.
[64] Ibid., 59-60.

astronauts and the CM.[65] During this time, the astronauts conducted the Light Flash Phenomenon Experiment and the Biological Cosmic Ray Experiment. (BIOCARE) This passive study sought to determine if cosmic ray particles injured non-regenerative cells in the eye and brain.[66] The experiment consisted of five mice with cosmic ray detectors implanted under their scalps. These mice lived in an aluminum tube within the CM. Researchers designed the tube so there was no effect of zero-g on the mice, and scientists analyzed the detectors upon return to Earth.

NASA's final excursion to the Moon, Apollo 17, was a significant success. Faith in scientist-astronauts soared when Schmitt recovered a lunar rock that was later called "the most interesting sample retuned from the Moon."[67] Schmitt recovered Troctolite 76535 at station 6 and from it, scientists discovered that the Moon may have once had an acute magnetic field.[68] The surface astronauts also found orange colored material that led scientists to discover the sample was volcanic in origin.[69] Apollo 17, the final lunar landing, holds many records for the space program. The second EVA holds the record for the furthest and longest activity ever carried out.[70] The astronauts spent 7 hours and 37 minutes on the surface and covered over 1935 kilometers of terrain. For an agency created in the midst of the Cold War and driven by Cold War objectives, Apollo 15, 16 and 17 transformed NASA into a scientific data gathering powerhouse backed by scientists. NASA had pulled itself away from political rhetoric and operated on missions of pure scientific curiosity. The tenacity of NASA administrators and

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[65] Ibid., 18.

[66] Ibid., 62.

[67] NASA Johnson Space Center, Lunar Sample Compendium, Charles Meyer, 20060011039, Houston, Texas, April 2006, accessed December 15.2017, www.curator.jsc.nasa.gov/lunar/lsc/76535.pdf.

[68] Kenneth Chang, "Rock Suggests Early Moon's Fiery Core Churned a Magnetic Field," *New York Times*, January 19, 2009..

[69] National Aeronautics and Space Administration, "Apollo 17 Post-Mission Operation Report," in *Apollo 17: The NASA Mission Reports*, 125.

[70] Ibid., 129.

scientists changed how science was seen within the agency’s doors. From Apollo 1 having a small science package to Apollo 17 covering thousands of kilometers of the lunar surface and deploying the most high-tech data gathering instruments to date, NASA changed science. The personnel and scientists involved were not content serving as pawns of the power politics of the Cold War. Apollo 17 ensured the lunar landing phase of Apollo finished strong, and it paved the way for Skylab and the Apollo-Soyuz Test Project to complete NASA’s initial post-Moon strategy.

Chapter 4: Skylab: Maximizing Scientific Potential

I: Creation of America's First Space Station

Following the successful completion of NASA's manned lunar program, the space agency moved to its next phase of manned spaceflight. The plans for what lay beyond Apollo dated back to 1963, while NASA finished up Project Mercury. During this period, the Office of Manned Spaceflight at NASA began advocating post-Apollo to the United States Congress. The OMSF believed that ending the program after landing on the Moon would be a waste of the resources that had been put into the space program thus far.[1] Post-Apollo plans would justify the massive spending on Apollo's rockets, spacecraft, and launch facilities to conduct more missions in order to produce more return on America's investment. In many ways, NASA used its post-Apollo planning to keep itself relevant in a world no longer in awe of spaceflight. The 1964 President's Report to Congress on US Space Activities reflected the opportunity the OMSF laid out. The report examined three possibilities: Apollo spacecrafts and system could be used for Earth and lunar missions, extension of the Apollo program with modification of existing systems or new hardware development for new mission concepts.[2] The president's council on space highlighted that these new mission concepts could take the form of Earth orbital operations, lunar operation, and planetary operations. The following year, the council went into further detail about the Apollo Applications Program (AAP), the name for NASA's post-Apollo activities. In 1965, the president's council defined the following as the goals of the AAP: "Develop operational equipment and techniques, to obtain direct benefits to men, and to conduct further

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[1] Compton, *Where No Man Has Gone Before,* 65.

[2] NASC, *U.S. Aeronautics and Space Activities: 1964*, 17.

scientific exploration of space."[3] As discussed in chapter 1, NASA had not yet committed to science as a cornerstone of its space program in the 1960s. However, the inclusion of science objectives in the president's report shows that the agency's thinking about pushing scientific discovery as a larger part of its plan. To accomplish the goals of AAP, the Apollo-Saturn systems continued to be used. NASA and the president's council narrowed its post-Apollo options to building a space station with a shuttle system, missions returning to the Moon, and looking toward Mars.[4] However, the exact nature of AAP had not yet been defined.

AAP began to take on a clearer picture in 1966 when NASA reported to the President's Council on Space Activities that the agency planned to convert the second stage of the Saturn V rocket into a habitable space station.[5] An airlock allowed astronauts to live and work within an "orbital workshop" that resided in low-Earth orbit. NASA made developmental strides toward realizing a low-Earth orbit space station but did not want to commit to only one objective for AAP. Yet, outside forces put the agency's grand plans on halt and forced NASA to scale back its post-Apollo hopes.

Following NASA's peak budget years, the purse strings began to tighten after 1966, beginning with the Apollo 1 fire. As discussed in previous chapters, after the investigation into the fire and congressional hearing, budget allotments for NASA began decreasing with every subsequent year. NASA's administrators and leaders were forced to funnel as much money as possible into the Apollo program. This did not leave much for developing and planning AAP.[6]

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[3] National Aeronautics and Space Council, *U.S. Aeronautics and Space Activities, January 1 to December 31, 1965, Report to Congress from the President of the United States* (Washington DC, January 31, 1965), 16-17, https://history.nasa.gov/presrep1965.pdf.

[4] NASC, *U.S. Aeronautics and Space Activities: 1964*, 17-18.

[5] NASC, *U.S. Aeronautics and Space Activities: 1966*, 18-19.

[6] Brooks et al, *Chariots for Apollo*, 189.

George Mueller announced that AAP would serve as a bridge to the next space program rather than stand out on its own and be a long-term program.[7] AAP's goals would no longer be on equal priority with Apollo. The post-Apollo program took another hit when NASA scaled back its goals and announced that the AAP would only include the orbital workshop with the Apollo Telescope Mount and development of a low-cost transportation system.[8] Fiscal 1968 would signal the end of unrestricted spending for NASA and AAP took the largest cut. While Apollo's budget faced a 2% cut, AAP was cut 31%, and all other space science programs were cut 22%.[9] This budget signaled a change in national priorities, and scientific exploration of space was now low on that list. NASA would face further scrutiny in its post-Apollo objectives when the new Nixon administration took office in 1969.

In early 1969, President Nixon created the Space Task Group to propose post-Apollo alternatives and activities.[10] The STG wanted NASA to pursue a balanced manned and unmanned program. The president's group advocated that the agency should adopt a long-range goal to sustain itself for the next 8 years. The STG suggested that NASA commit to an earth orbiting station, lunar base, and a manned mission to Mars by the 1980s, or an unmanned mission to Mars to allow the agency to set a date for a manned mission, or finally, a space station, shuttle vehicle, and setting a manned mission to mars to be completed before 1999.[11] President Nixon was not very receptive to any of the proposed plans due to his focus on domestic issues and solving the puzzle of ending the Vietnam War. As discussed previously, government

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[7] Compton, *Where No Man Has Gone Before*, 102-103.
[8] National Aeronautics and Space Council, *U.S. Aeronautics and Space Activities, January 1 to December 31, 1967, Report to the Congress from the President of the United States* (Washington D.C. January 1968), 13, https://history.nasa.gov/presrep1967.pdf.
[9] Compton, *Where No Man Has Gone Before*, 101-102.
[10] Compton, *Where No Man Has Gone Before*, 193-196.
[11] Ibid.

support drained when public reaction to a Mars mission ran overwhelmingly negative in both the general population and scientific community. NASA continued to work on the orbital workshop concept, however beyond that, the agency did not know what the next step would be.

The end of the 1960's and early 1970's should have been a high point for NASA with the realization of landing men on the Moon and five more successful landings. However, the congressional historian on the House Committee on Science and Technology Ken Hechler summed up the early 1970's as "the worst of times for the space program."[12] He lamented the wane of NASA's triumphs:

> By hindsight, it seems unlikely that even the strongest and most adept mobilizations of the supporters of more manned flights to the Moon could have successfully overcome the adverse feeling in the country in the early 1970's. Congress and the Nation could be persuaded to support Skylab, the space shuttle, and a modest level of activity by NASA in other areas. But… Von Braun's dream of a manned flight to Mars was not in the cards for the 20th Century, at least.[13]

NASA faced low public interest, minimal governmental support, and mission cancellations in the last years of Apollo. What resulted was a neutered AAP and no direction following the program's completion. However, as seen in the final stages of the Apollo manned lunar mission, NASA used its remaining time to invest in scientific objectives to maximize scientific returns. The orbital workshop, named Skylab, would be NASA's conduit to show its full scientific potential.

Mission planning for Skylab began in 1969. NASA wanted the first workshop mission to be a 28-day duration mission with two more revisits that consisted of 56 days each.[14] Skylab

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[12] Ken Hechler, *Toward the Endless Frontier: History of the Committee on Science and Technology* (Washington D.C.: U.S. House of Representatives, 1980), 313-314.

[13] Ibid.

[14] NASC, *U.S. Aeronautics and Space Activities, 1969*, 8.

would be completely outfitted on the ground, then launched into orbit. This method of dry launching was not more cost effective than a wet launch, where the rocket stage was launched then its contents, fuel and other propellants were vented, and the workshop was modified later. NASA chose the dry method over wet for several reasons: modification of the S-IV had progressed already, and cancellation of Apollo 18 through 20 freed up powerful boosters to send a dry station into orbit.[15] With the outfitting of Skylab progressing quickly with a goal of launching in 1973, NASA administrations and mission planners set the objectives for the orbital workshop:

> The Program's objectives are: to determine and evaluate man's psychological responses and aptitudes in space under zero gravity conditions and his post-mission adaptation to the terrestrial environment through a series of progressively longer missions; to develop and evaluate efficient technologies for utilizing man in sensor operation, discrimination, data selection and evaluation, manual control, maintenance and repair, assembly and installation of hardware components, and mobility involved in various operations; to develop techniques for increasing system's life for long duration habitability and long duration mission control and to investigate and develop techniques for inflight test and qualification of advanced subsystems; to conduct astronomy and pother science, technology, and application experiments in which man's contribution is expected to improve quality and/or yield of the results.[16]

Skylab was an ambitious endeavor planned by NASA. Based on Skylab's objectives, NASA brought together everything the agency learned in the Mercury, Gemini, and Apollo programs in the outline for Skylab. As opposed to early American manned spaceflight, NASA planned Skylab to be a melding of scientific and engineering milestones. This was evident in the space administration's strategy of loading up Skylab to maximize its scientific potential.

II: The Science of Skylab

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[15] Compton, *Where No Man Has Gone Before*, 194-196.

[16] NASC, *U.S. Aeronautics and Space Activities, 1970*, 13.

NASA outfitted the Skylab orbital workshop with the latest and most advanced scientific data gathering devices created at the time. The standout among cutting-edge technology was the Apollo Telescope Mount (ATM). The base of the ATM was a modified lunar module.[17] Designers equipped the ATM with eight large telescopes that were used to observe various astronomical phenomena. Two of the telescopes looked at the sun in visible wavelengths called hydrogen-alpha radiation that came from excited hydrogen atoms in the solar atmosphere.[18] Three telescopes were sensitive to extreme ultraviolet radiation, while two other telescopes were sensitive to the x-ray portion of the spectrum. The final telescope in the ATM, the White Light Coronagraph, observed the Sun's corona when the workshop rotated to the dark side of the Earth's orbit without requiring total solar eclipse. The ATM was the first active solar observatory launched by the United State. Previously, the Americans launched probes, such as the Pioneer series, to observe the Sun. The benefit of the ATM to scientists was that now they actively engaged in the objectives and operation. While Skylab was in orbit, the ground science team debated the best use of the ATM for the 50 minutes of sunlight every 24 hours.[19] When the science team settled on a plan, it was sent to the crew and the orbital activity was completed. This method of scientific activity was far different from early Apollo. The ATM and Skylab dramatically demonstrated that NASA had unleashed their scientists. They now directly shaped mission plans and objectives for the purposes of science experimentation.

The increased scientific potential of Skylab showed bright when NASA reused the proven ALSEP concept from the moon landings. While the ATM looked outward, the Earth

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[17] NASC, *U.S. Aeronautics and Space Activities, 1966*, 18-19.

[18] David Hitt, Owen Garriott, and Joe Kerwin, *Homesteading Space: The Skylab Story* (Lincoln: University of Nebraska Press, 2008), 425.

[19] Ibid., 426.

Resources Experiment Package (EREP) looked toward Earth. The package contained sensors that allowed astronauts to gather data on geological, geographical, hydrological, agricultural, forestry, oceanographic, and metrological studies of selected ground targets.[20] NASA created the EREP as an international project. In December 1970, NASA sent out invitations for participation in space flight investigations to U.S. and foreign scientists.[21] It received over 300 proposals and hosted representatives from 40 countries and 16 international organizations at the International Workshop on Earth Resources at the University of Michigan. The EREP became a symbol for international scientific cooperation during the period of Cold War Détente.

High among its objectives, Skylab planned to measure human response to extended period of weightlessness in an effort to plan for future deep space exploration missions. One way to accomplish this goal was the creation of a medical plan that was completed during Skylab's operational tenure. To study heart function during exercise and simulated gravity, measurements were taken while astronauts rode an exercise bike every 4 days in flight.[22] Monitors gathered data on heart rates, blood pressure, oxygen consumption, and carbon dioxide production and compared the data taken earlier from the astronauts on Earth. Doctors also investigated metabolic balance with measurements of all input and output along with pre- and post-flight bone loss using gamma radiation experiments. They also investigated stress levels throughout the missions through blood samples taken and frozen during flight. Following return to Earth, samples were analyzed, and hormone levels were measured. Finally, to investigate motion sickness in weightlessness and space flight, the astronaut's vestibular balance system of the inner ear was measured and evaluated. To accomplish many of these experiments during the Skylab missions,

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[20] NASC, *U.S. Aeronautics and Space Activities, 1970*, 13.
[21] NASC, *U.S. Aeronautics and Space Activities, 1971*, 14.
[22] Hitt et al., *Homesteading Space*, 413.

designers created a method of measuring weight in a weightless environment. Dr. Bill Thornton, a scientist-astronaut, who would go on to be a support crew member for all three Skylab missions and shuttle astronaut, formulated an experiment for mass measurement in a weightless space.[23] He found that if one measured the time a strip of steel oscillated when attached to an object, the relative weight could be determined by observing the rate of oscillation. The higher the oscillation, the more weight an object has. The Air Force went on and produced measuring devices for Skylab, one for measuring astronauts and two to measure food, reserves, waste, and other small items. NASA's future after 1975 remained unclear, yet this did not stop the agency from planning for its next step.

Many aspects of Skylab finally realized the fusing engineering and scientific techniques and inquiry. Experiments on the habitability of a space station conducted during the three orbital missions highlighted this fusing. While these experiments did not have active data collection, scientists evaluated experiment planning based on astronaut feedback and testing of the workshop's amenities. Experiment M487, known as habitability/crew quarters experiment, sought to "measure, evaluate and report habitability features of crew quarters and work areas of Skylab in engineering terms useful to the design of future spacecraft."[24] Experiment M516, known as crew activities/maintenance study, planned "to evaluate Skylab man-machine relationships by gathering data concerning the crew's capability to preform work in the zero-g environment and long duration missions."[25] To gather data to satisfy these experiments' parameters, astronauts tested restraints, handholds, equipment features, how doors open, and

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[23] Ibid., 407.
[24] Ibid., 437-438.
[25] Ibid.

aesthetic design of modules. Feedback from astronauts allowed NASA to begin toying with ideas for the next space program that would become the space shuttle and International Space Station.

Finally, NASA would foster scientific thinking and creativity in the next generation of scientists by creating the Skylab Student Project. Sponsored by NASA and national science teacher's associations, the project allowed secondary education students to propose experiments to be included and completed on Skylab.[26] NASA sent requests for proposals to all fifty states and nine overseas high schools. Students from 7th to 12th grade could propose experiments on astronomy, botany, earth observation, microbiology, physics, physiology, and zoology.[27] Twenty-five winners were chosen and of those, twenty-two flew on Skylab. For eleven of the student experiments, NASA and its scientists developed new hardware to accomplish its objectives. The Skylab Student Project was a high point for NASA's scientific strategy on Skylab. Pure scientific inquiry and imagination fueled the project. Jack H. Waite, the technical assistant to the manager of the Space Science Project Office at Marshal Space Flight Center, detailed why the student program was created:

> The Skylab Student Program came into being because some of us involved in the space program were concerned over the decline in interest of our youth in science and engineering fields in 'post-Apollo' days…A number of NASA headquarters and field center personnel discussed ways to stimulate the American youth interest in these fields. It became apparent that they could, even should, be an integral part of the Skylab Experiment Program.[28]

As seen previously, many government officials had a hard time condoning space activity for reasons other than national prestige. The student program let NASA advance more reasons why their program of science-based objectives and agency goals should continue. Generating

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[26] NASC, *U.S. Aeronautics and Space Activities, 1971*, 14.
[27] Hitt et al., *Homesteading Space*, 440.
[28] Ibid.

American youth interest in the sciences was an area that allowed NASA to give back to the nation for all the expenditures of going to the Moon. More simply, the Skylab Student Project was a throwback to Administrator Webb's push for "ideas first." NASA designed Skylab with an ambitious experimental schedule, and with that came problems.

III: Skylab: Science in Orbit

The Skylab workshop launched with high hopes on May 14, 1973, but the station became immediately fraught with complications. During launch, one of the workshop's sun shield/shades tore off and the second pinned shut.[29] Without these shades, the workshop's power disappeared, and the interior filled with toxic materials due to rising temperatures. NASA postponed the first manned launch to Skylab from May 15 to the 25th in order to practice replacing and repairing the solar shields. Following the successful launch and repair during SL-2, 80 percent of the planned solar data was obtained, 12 of 15 EREP data runs were completed, including microwave measurements of Hurricane Ava in the Pacific Ocean, and 16 medical experiments were run.[30] SL-3 had even more success when, after overcoming motion sickness, the crew carried out unscheduled tests and experiments that went over pre-mission planning.[31] SL-4, had problems keeping the trend of work up. The all-rookie crew found their tasks overwhelming and flight controllers felt the crew took too long to accomplish basic objectives. Perhaps due to the success of previous flights, the crew felt that mission control had asked too much of them and "mutinied" by switching off communications with Earth for a while and relaxing.[32] Following an airing of grievances, mission control modified the workload schedule, and the mission ended up

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[29] National Aeronautics and Space Council, *U.S. Aeronautics and Space Activities, January 1 to December 31, 1975, Report to the Congress from the President of the United States* (Washington D.C. January 1976), 15.

[30] Ibid., 15-16.

[31] Ibid., 16.

[32] Ibid.

accomplishing more than originally planned. The crew returned home while Skylab remained in orbit. NASA planned to return with the shuttle by the 1980s, but the craft was not ready in time, and Skylab's orbit degraded. The workshop reentered earth's atmosphere in July 1979 and broke up over South Africa and Western Australia.

Skylab's legacy lies in the diversity of its scientific experiments and accomplishments. Those outlined above were very different in scale and object. Some experiments cost millions upon millions of dollars while one cost $3500 dollars and a few minutes of the astronaut's time.[33] Don Lind, backup crew member for SL-3 and SL-4, noted his contribution to experimentation on Skylab amounted to suggesting putting a piece of tinfoil on the struts of the ATM so one could see an aurora caused by particles headed to Earth and an astronaut could grab the piece on the way to retrieve the ATM's film canister. NASA official William C. Schneider said that this was his favorite experiment because it was one of the cheapest experiments that flew in space. This willingness to try anything in the name of science became the hallmark of Skylab and the late Apollo program. This new culture and total commitment to science within NASA was the result of a Khunian "paradigm shift" and the conflict of ideas during the Space Race. Unfortunately, NASA was unable to completely stave off being dragged back into the politics of the Cold War and forced to sacrifice scientific achievement to satisfy political agenda.

IV: NASA Is Pulled Back into The Cold War

As previously seen in the culling of NASA's budget and mission cancellations during the early years of the Nixon administration, the space agency saw few plans come to fruition following the final moon landing in 1972. Skylab used leftover spacecraft and repurposed them

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[33] Hitt et al., 442-443.

for a scientific mission. President Nixon and his administration moved their focus to ending America's involvement in Vietnam and to easing tensions with the Soviet Union. This policy of Détente pulled NASA back into the political arena of the Cold War and ended the scientific renaissance it experienced following the first moon landing.

The policy of Détente during the Cold War was born out of two powers seeking global stability following decades of tension and wars. Both sides wanted to show that they could work together in peace and become leaders without being enemies.[34] Space cooperation became an arm of this policy in 1970. The Soviet Academy of Sciences, the USSR's space agency, and the National Academy of Sciences began to talk about the possibility of collaboration.[35] In May 1970, Dr. Phillip Hendler, the president of the National Academy of Sciences, brought a plan before Mstislav Keldysh, the head of the Soviet Academy of Sciences. The proposal included a docking device that could link up American and Soviet spacecraft in orbit.[36] Keldysh agreed, and the two superpowers began to work on a joint mission: the Apollo-Soyuz Test Project (ASTP).

The proposed mission to be launched in 1975 involved the rendezvous and docking of a leftover Apollo CSM and a Salyut space station.[37] However, the Soviets became concerned they would be unable to outfit and launch a station by 1975. The mission was changed to a linkup

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[34] On the impulses driving Détente see Jeremi Suri, *Power and Protest: Revolution and the Rise of Détente* (Boston: Harvard University Press, 2003), and Jussi Hanhimaki, *The Rise and Fall of Détente: American Foreign Policy and the Transformation of the Cold War* (Washington D.C.: Potomac Books, 2013): also see Wilfried Loth, *Overcoming the Cold War: A History of Détente* (London: Palgrave-MacMillan, 2002), and Stephan Kieninger, *Dynamic Detente The United States and Europe, 1964-1975* (Lanham, MD: Roman and Littlefield Press, 2016).

[35] Jack Manno, *Arming the Heavens: The Hidden Military Agenda for Space, 1945-1995* (New York: Dodd, Mead & Co., 1984), 132.

[36] Alan Shepard at al, *Moonshot: The Inside Story of America's Race to the Moon* (Atlanta: Turner Publishing, 1994), 327.

[37] "Minutes of Senior Group Meeting," February 11, 1972, in *Foreign Relations of the United States, 1969-1976*, Volume XIV, Soviet Union, October 1971- May 1972, David C. Geyer, Nina D. Howland and Kent Sieg, eds., (Washington D.C.: United States Government Printing Office, 2006), 162-165.

between an Apollo capsule and a Soyuz capsule using the docking module.[38] Both nations had complex set of reasons for joining and pursuing this joint mission. While America found success going to the Moon, the USSR was successful at making stations in low Earth orbit and ferrying cosmonauts up and down to them at a regular pace. However, following the moon landings and end of Skylab, NASA found itself with no planned missions until the space shuttle that was planned to first launch in 1981. This gap, along with the budget cuts, created a surplus of astronauts and hardware for the United States. On the other side, the Soviets needed a high-profile mission following the Soyuz 11 accident in 1971.[39] Following the reentry and landing of the Soyuz 11 capsule, the three cosmonauts inside were found dead. A leaky valve in their capsule caused the air to leak out and asphyxiated the cosmonauts.[40] This tragedy, along with economic woes in the Soviet Union caused its people to question their support for the Soviet space program in the 1970s. A February 1971 *Washington Post* story recounted a large shipment of rotten potatoes in the Soviet Union. An outraged Russian woman shouted "we have rockets, right? Of course, right. We have *Sputniks*, right? Of course, right. They fly beautifully in outer space. So, I say to you dear friends, why don't we just send these rotten potatoes into outer space too."[41] The Russian people were beginning to be irritated by the costly space program while many went hungry in the streets. Both sides had reasons why they needed this joint mission to work and look good.

Following the successful launch and rendezvous of the Apollo and Soyuz capsules on July 17, 1975, the two spacecrafts docked, and made history when the two crews joined each

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[38] Tom D. Crouch, *Aiming for the Stars: The Dreamers and Doers of the Space Age* (Washington D.C.: Smithsonian Institute Press, 1999), 78.
[39] Ibid., 77-78.
[40] Manno, *Arming the Heavens*, 133.
[41] Asif A. Siddiqi, *The Soviet Space Race with Apollo* (Gainesville: University of Florida Press, 2000), 794.

other and shook hands. The ASTP was a profoundly political mission. Once again, the engineering and political milestones and objectives vastly outweighed the scientific tasks. Beholden to the US political system and forced by the Cold War, NASA to put aside its scientific ambitions to serve as a political power play. However, the political nature of the mission did not stop NASA from flexing its scientific discovery muscle. Over the next few days following the docking, the crews carried out experiments, both separately and together.[42] Apollo carried equipment for twenty-three science and technical experiments. Soyuz carried six experiments in astrophysics and biology. Five joint experiments were planned to be completed while docked and undocked.

Following the successful completion of the ASTP, NASA looked forward to further cooperation with the Soviets. In 1974, NASA proposed the shuttle would fly to a future Salyut station and dock with it in order to test the building of an international space station.[43] The Russians responded that they wanted to wait and see the outcome of ASTP first. In May 1975, George Low submitted an idea for an astronaut/cosmonaut swap and a space station linkup, but again the Russians wanted to wait until ASTP was completed. Nothing new occurred until 1977 when the two nations signed an agreement to look at possible future missions in space cooperation.

However, the change in political climate broke down this cooperation. President Jimmy Carter grew increasingly concerned with the Soviet suppression of the Polish Solidarity Movement.[44] Conflicts between the US and USSR over Ethiopia, Angola, Shaba, Yemen,

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[42] Walter Frochlich, *Apollo-Soyuz* (Washington D.C.: NASA Office of Public Affairs, 1976), 72.

[43] Crouch, *Aiming for the Stars,* 80.

[44] Matthew J. Von Bencke, *The Politics of Space: A History of U.S.-Soviet/Russian Competition and Cooperation in Space* (Boulder: Westview Press, 1997), 87.

Cambodia, and Cuba occurred throughout the late 1970s. The Soviets, worried about US attempts to militarize space, demanded that NASA discontinue its development of the shuttle program if the 1977 agreement was to go ahead. This was seen as impossible for NASA and the government who saw the shuttle as the next step in the US space program. Finally, the December 27, 1979, invasion of Afghanistan by the Soviet Union broke the agreements. The age of cooperation would be over, and the Cold War would reignite once again.

After six Moon landings and three Skylab missions, NASA had become adept at flying science-based missions. Once the agency shed the moniker of fighting the Cold War, it became a science-driven organization. NASA contributed cosmic amounts of data to the body of scientific knowledge. However, it was unable to fully secure its freedom from political agendas and was dragged back into the Cold War when the nation’s objectives required it to. Following the ASTP, NASA hibernated and began work on the next phase of its manned space program but would not launch humans back into space until 1981. Working on the shuttle kept the agency in business, but it would not have the scientific triumphs that were seen from 1969 to 1973 for many years.

NASA’s Internal Motives Versus Political Games

Throughout the 1960’s to the mid-1970’s, NASA remained a pawn of the grand Cold War stratagem for the United States. Science was a pawn in the political game as well. NASA explored increasing science’s priority in a broad space program, but the agency knew when to pull back and realign itself with United States’ goals when called upon. As NASA moved around the Cold War boardgame, the agency itself moved science in and out of mission prioritization. The agency had to continually justify and modify its scientific pursuits according to its political and economic benefactors. Because of this, NASA, in order to accomplish its scientific goals, acquiesced and played the game of power politics depending on the stage of the Cold War. Positivist historians of the early 20th century would have viewed NASA’s science endeavors in a vacuum, but the agency’s department heads and scientists were not immune or left alone by the political context of the Cold War. However, despite the constant economic and political changes of those 15 years, NASA personnel completed political engineering objectives and accomplish a comprehensive scientific program.

The first Moon landing was a mission of engineering triumph, but it was a triumph of politics over science. However, as each Apollo moon landing succeeded, NASA’s science strategy became bolder. This was due in part to fewer eyes watching following the first lunar landing in 1969. NASA proved itself and made flying missions to the moon “routine.” This allowed it to increase stays on the lunar surface, equip the astronauts with new tools and a vehicle, and increased the complexity of scientific experiments deployed and tested. All of this work culminated in Skylab, which was a pure scientific endeavor by NASA. Unburdened by political games, NASA pushed its science program further than ever. Later, the Cold War pulled

NASA back into the political arena when it was asked to collaborate with the USSR in Apollo-Soyuz and the agency shifted again.

NASA's style of bending to politics would continue to serve it long after completion of the Apollo Program. The space shuttle was created in response to economic uncertainties of the 1980s. And once the public no longer had a love affair with space exploration, NASA searched for other avenues of spaceflight. The boom of private space ventures in the new millennium has led NASA to partner and shift some of the economic burden off the taxpayers. This could allow a new Space Race between private companies with NASA footing the experience and reaping the scientific benefits as seen during the race to the Moon in the 1960's.

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