When Big Science Fails: The Hubble Space Telescope Flaw and Implications for the Space Program in the Post-Cold War Era

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Abstract

This thesis addresses how the development of the Hubble Space Telescope and the reaction to its initial mirror flaw illustrates the systemic issues affecting large-scale science in the U.S. civil space program. The socio-economic and political legacy of the prestige-driven space race in the 1960's impacted the development of programs such as the Space Shuttle and Hubble in a way which both allowed them to be possible and curtailed their ability to succeed. The reaction to the Hubble flaw and other problems in the late 1980's and early 1990's, as seen through newspaper articles and congressional hearings, illuminates the complexity of Big Science programs and the extent to which they are affected by factors other than science. Actor-Network theory is used in part as a framework to address the power of different technological, human, and bureaucratic entities within the vast developmental and technical structures of Big Science programs. This thesis argues that the misrepresentation and oversimplification of scientific and technological entities as a symptom of large-scale technological development during the Cold War has had a significant impact on the contemporary structure of aerospace and astrophysical sciences in the United States.

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Introduction

"For most science news to get printed these days it has to involve big bang, big bucks, big screwup, or big comeback—and with Hubble you've got them all."¹ A writer for the New York Times described the highly publicized and volatile position of the Hubble Space Telescope's launch and subsequent issues which took place in the early 1990's. "Big science" is generally defined as post-WWII scientific programs which require generous amounts of funding and are developed with the resources and expertise of many different agencies, groups, institutions, and governments. As one of NASA's first "big science" programs which was developed without an overt military pretext, the perceived success or failure of Hubble was used as a way to validate or undermine the competency of NASA and the necessity of space science. Hubble came to fruition after the Cold War had technically ended, however the infrastructure of its development was rooted in military, political, and economic trends which characterized the early space race. Although Hubble has become a success story for NASA, the history of its development illuminates the growing technical and political complexities of big science projects as well as the civil space program's inability to extricate itself from its Cold War past. The problems experienced by Hubble in the early 1990's manifested from prolonged systemic issues in the space program and demonstrated the vulnerability of big science to technical failure, budgetary restraints, management issues, and intense public critique. The political and popular reactions to the initial Hubble flaw exposed the precarious position of NASA science programs and the overall vulnerability of big science and the American space program in the post-Cold War era.

It is useful to address the variety of socio-cultural forces which influence technological events and trends, however the impact and power of technological and scientific entities alone is

¹ Eric J. Chaisson, *The Hubble Wars: Astrophysics Meets Astropolitics in the Two-Billion Dollar Struggle over the Hubble Space Telescope* (New York, N.Y.: Harper Collins, 1994), 367.

not often considered in a significant way. This thesis attempts to address the economic and sociopolitical historical trends which have cumulated in the Hubble Space Telescope and the current space program in the context of changing perceptions of science as well as acknowledging the role of technology as a significant independent force in the networks which compose large scientific programs. Actor-Network theory provides a framework to consider technological entities such as Hubble as agents within the contexts of the massive networks of people, agencies, institutions, and other participants which facilitate and allow technological objects to exist. The actor-network model allows technological trends to be addressed more comprehensively as part of a multivariate fluctuating system and without reducing technological objects to the social meanings which are applied to them. Technological objects often come to be broadly represented through narrow channels such as a single presidential address, a congressional report, or a national headline. These are all useful resources in which to address the cultural import and historically situated discourse surrounding the development and reception of scientific programs, however, they do not promote an in depth understanding of the vastness or complexity of interrelated factors which ultimately manifest themselves in seemingly finite technological objects like the Hubble Space Telescope.

The Hubble Space Telescope was the largest and most technologically advanced civil scientific instrument of its time and as such it was developed among an even larger and more complex scientific and bureaucratic network over the course of many decades. Upon its launch in 1990 it was revealed to have a flawed lens, an issue which was utilized by politicians and the media to vilify the overall state of NASA and the national space program. Hubble's role as a representation of the national space program and a proxy for broader criticisms reflect the struggle of NASA to define itself beyond the military impetus of the Cold War and the struggle

of the American public to reconcile deep seated cultural memories of American exceptionalism in space with the realities of contemporary failures. The sheer enormity of big science programs make instruments like Hubble possible, but they also foster alienation between scientists and the general public. Hubble is a somewhat exceptional case of public redemption and unarguable

scientific success in the modern U.S. space program, but it also demonstrates the inescapable impact of powerful military and economic actors to affect the success and perception of civil science programs. Although Hubble has been a mainstay for NASA since the space telescope was successfully repaired in 1993, it has also encapsulated a post-Cold War shift towards privatization and changing cultural priorities in space.



Image 1: Eagle Nebula, 1995 Hubble photo. Source: NASA, ESA, Hester & Scowen ASU.

Many of the conflicting viewpoints between politicians, scientists, the media, and the public, emerge in part out of the underlying struggle to negotiate the definition of "Science" and the roles that science and scientists should be expected to play. The cultural definition of science has changed over time as has the perception of the national space program and those entities involved with it. The broader perception of science is important because the nature of the relationship between scientists and non-scientists has a significant impact on the planning, development, and reception of large aerospace programs such as Hubble and the space shuttle.

Chapter 1: Defining the Role of Science

The broader public and news media often perceive science as a neutral entity which is subject only to the data and "hard" facts gathered in the search for the truth. Robert K. Merton, the founder of the sociology of science, established a set of norms in 1942 which he believed represented the work of scientists. Merton's five norms, "CUDOS", consisted of: communalism, universalism, disinterestedness, originality, and skepticism.² Although most of these norms have since received criticism within the scientific community, they represented "a persuasive formulation of the academic: detached, methodical and committed to the search for the truth rather than personal glorification." ³ Despite the inherent and widespread influence of political, economic, and social agendas on scientific work, the idea of a neutral and altruistic science is still an omnipresent concept.

The idea of scientific facts being the constructions of individuals and processes, rather than preexisting truths uncovered only via research and an epiphanic moment has been raised by a number of scholars. Sociologists of science Bruno Latour and Steve Woolgar argued that facts are socially constructed (or, merely *constructed* as Latour and Woolgar later contend that the pervasiveness of the term "social" has rendered it meaningless for their purposes)⁴ and that "the process of construction involves the use of certain devices whereby all traces of production are made extremely difficult to detect."⁵ They elaborate on some of the issues associated with the social study of science:

...we regard it as instructive to apprehend as strange those aspects of scientific activity which are readily taken for granted. It is evident that the uncritical acceptance of the

² Robert Merton, "The Normative Structure of Science," in *The Sociology of Science: Theoretical and Empirical Investigations*, ed. N. Storer (Chicago: The University of Chicago Press, 1942), 267-278.

 ³ B. Macfarlane, and M. Cheng. "Communism, Universalism, and Disinterestedness: Re-examining Contemporary Support among Academics for Merton's Scientific Norms," *Journal of Academic Ethics* 6, no. 1 (2008): 69-70.
⁴ Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton: Princeton)

University Press, 1986), 281.

⁵ Ibid, 176.

concepts and terminology used by some scientists has had the effect of enhancing rather than reducing the mystery which surrounds the doing of science. Paradoxically, our utilization of the notion of anthropological strangeness is intended to dissolve rather than reaffirm the exoticism with which science is sometimes associated.⁶

The specialized language and culture of science can serve to further mystify scientific practice and scientists themselves, contributing to perceptions of elitism and detachment. Francesca Polletta of the sociology department at the University of California, Irvine, argued in a 2011 article that "what passed as universal categories, neutral standards, scientific facts, and objective progress were actually stories: moralizing accounts whose claim to truth rested on their verisimilitude rather than their veracity."⁷ The idea of scientific facts being constructed at least in part by way of microprocesses, internal scientific discourses, competition over authorship, and other factors comes in to direct conflict with Merton's initially established norms and in conflict with the mainstream perception of a neutral or pure science.

It was not until the second half of the twentieth century when the idealization of scientific neutrality began to be questioned by sociologists. Sal Restivo, a prominent scholar in the field of social science and technology, argued that it "required the political and social upheavals of the 1960's to sufficiently tarnish the image of science and scientists and create an intellectual atmosphere in which the sanctity of scientific knowledge itself could be challenged." ⁸ In addition to the fears of growing corruption of the scientific community by political and military interests expressed by President Eisenhower and Alvin Weinberg in 1961, Eisenhower argued that "we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite."⁹ There was a latent perception that the

⁶ Ibid, 29.

⁷ Francesca Polletta, et al. "The Sociology of Storytelling" Annual Review of Sociology 37 (2011), 111.

⁸ Sal Restivo, *Science, Society, and Values: Toward a Sociology of Objectivity,* (London: Associated University Presses, 1994), 4-5.

⁹ Eisenhower, "Farewell Address," 18-19.

utilitarianism of the scientific method was not necessarily governed by a distinct code of ethics and could therefore be a potential threat to social interests or human safety. Weinberg and some of his contemporaries likened this idea of a "dominant scientific caste" to that of a religious priesthood, in which knowledge is sacred, immutable, and only knowable to a relatively small subsection of society.¹⁰ The discussion of technology at the time took place in the constant shadow of the atomic bomb, which brought to the forefront the destructive potentiality of science and instigated fear of unbridled scientific development in general. Addressing this fear of misplaced scientific power, Eisenhower stipulated that "only an alert and knowledgeable citizenry can compel the proper meshing of the huge industrial and military machinery of defense with our peaceful methods and goals."¹¹ It became clearer throughout the mid-century that science, and the relatively few who understood and were seen to command it, had to somehow be kept in check with the moral and political expectations of American society.

The presence of a scientific and technological elite was and is still seen as a potential threat to democratic systems, as expressed long before the 1960's by President Woodrow Wilson:

God forbid that in a democratic society we should resign the task and give the government over to experts. What are we for if we are to be scientifically taken care of by a small number of gentlemen who are the only men who understand the job? Because if we don't understand the job, then we are not a free people.¹²

The conflict between politicians with the agendas of their respective constituents and parties in mind, and specialized groups of scientists who are often the recipients of some kind of government sponsorship is an ongoing source of controversy especially when it comes to very

¹⁰ Weinberg, "Impact of Large-Scale Science...", 1.

¹¹ Eisenhower, "Farewell Address," 18-19.

¹² Woodrow Wilson, as cited by Ralph Lapp, *The New Priesthood: The Scientific Elite and the Uses of Power*, (New York: Harper, 1965), 1.

large, expensive programs. Eisenhower said that it was necessary to "balance" and "integrate" these forces "—ever aiming toward the supreme goals of our free society."¹³ At the root of this idea is a disagreement about what is and is not "good" for the people of a democracy; an ambiguous question which is continually contested.

Technological and scientific objects and development exist in a "world made up of institutions, values, interest groups, social classes, and political and economic forces," but they are also a force in of themselves.¹⁴ Political and socio-economic trends and events are vital to the context in which technology and science manifests, however, technological objects are not merely passive reflections of the social contexts in which they appear. Rather, they are entities which can create historical change and alter discourse.

Drawing in part from Latour, Michel Callon argued that the unique influence and power of science and technology requires an analysis which surpasses traditional sociological confines and addresses networks composed of both human and nonhuman entities.¹⁵ By "introducing unpredictable variations and new associations" the changing nature of scientific and technological entities necessitates the constant "rebuilding" of connections between the social and the natural. Callon argued, among others, that the conceptual framework of actor-networks make it possible to "describe the content of technical objects and theoretical knowledge."¹⁶ In addition, John Law argued in a 1987 article that "historians and some sociologists are groping toward a method for studying the construction of and interaction between heterogeneous structures" and the actor-network framework

¹³ Eisenhower, "Farewell Address", 19.

¹⁴ Thomas P. Hughes, "Technological Momentum," in *Does Technology Drive History*? Edited by Merrit Roe Smith and Leo Marx (Cambridge, MA: MIT Press, 1994), 102.

¹⁵ Michel Callon, "The Sociology of an Actor-Network: The Case of the Electric Vehicle." in Michel Callon, John Law, Arie Rip, eds. *Mapping the Dynamics of Science and Technology* (London: MacMillan, 1986), 20. ¹⁶ Ibid., 23.

makes use of a vocabulary that does not distinguish among the social, the scientific, the technological, the economic, and the political, and makes no a priori assumptions that one of these carries greater explanatory weight than all the others. Rather, it displays the strategies of system-building and, in particular, the heterogeneous and conflicting field of forces within which technological problems are posed and solved.¹⁷

Law argued that to address social factors alone to analyze technological change is reductionary and significantly narrows the comprehension of scientific objects. Callon identified the process of translating large scientific networks for broader non-scientific audiences as a primary way in which they are often oversimplified and even trivialized.

The scientific or technical object is not experienced as a concrete entity until the actornetworks which constitute it are simplified or converted through the process of translation. Translation entails the simplification of large systems such as Hubble into something which can be represented and more easily understood as a singular object. Translation occurs in part when "entities are converted into inscriptions, reports, memoranda, documents, survey results, scientific papers...There are also movements of materials and of money. Translation cannot be effective, i.e. lead to stable constructions, if it is not anchored to such movements, to physical and social displacements."¹⁸ Translation is important to the way in which information is consumed, ultimately placing one or few institutions or entities in charge of projecting and displaying the scientific object which has manifested from an "infinitely complex world" of interacting networks.¹⁹

¹⁷ John Law, "On the Social Explanation of Technical Change: The Case of the Portuguese Maritime Expansion," *Technology and Culture*, Vol. 28, No. 2 (Apr., 1987), 252.

¹⁸ Callon, "Sociology of an Actor-Network...", 27.

¹⁹ Ibid., 29.

In the case of Hubble, NASA was largely the translator, or the most significant institution responsible for reducing and representing the configuration of networks which created the space telescope. Congress would ultimately refer to NASA officials and scientists for financial and technological reports, as well as relying largely on NASA as a regulating entity for contractors and scientific bodies involved in the development of Hubble systems. Callon stated that "to translate is to speak for, to be indispensable, and to displace. All translation works to

Successful translation quickly makes us forget its history."²⁰ This simplification and displacement inherent to the process of translation becomes very problematic when the system, or a single element of the system, fails. In this case,

solidify actor-worlds.



Image 2: Exploded View of the Hubble Space Telescope. Source: NASA, Lockheed, "Servicing Mission Guide," 1993.

Hubble was launched with a flawed primary mirror which quickly became evident through the blurrier than expected images which were widely publicized after being retrieved by NASA.

The 1990 Allen Commission which headed the Hubble flaw investigation attempted in part to grasp and identify the systemic issues which played a part in the failure, but ultimately it was NASA which had to absorb the majority of the blame. The way in which big science programs must be simplified into more easily digestible terms creates a distinct disconnect between scientists and everyone else. Not only does the reduction of an object like Hubble to a

²⁰ Callon, "Sociology of an Actor-Network...", 28.

few pages of a report or a few minutes in front of a committee misrepresent the magnitude of work involved in its construction, but it also makes Hubble and the entities and individuals which represent it extremely vulnerable to wide-ranging critique. In this case, NASA and NASA's entire culture was widely held responsible by politicians and the media alike, although Hubble constituted a system which existed far and beyond the confines of the American civil space agency. Eric Chaisson of the Harvard-Smithsonian Center for Astrophysics touched on some of the immense intricacies of Hubble's development:

All of us knew that the Hubble Space Telescope is the most complex piece of scientific equipment ever built by humans. "It's a little like being chief engineer for the pyramids," deadpanned Dave Skillman, the lead Hubble engineer at Goddard...Not just the most powerful telescope or the most expensive scientific gadget, Hubble is also hellishly complicated to schedule and operate effectively. The magnitude of the effort needed to build just the Science Operations Ground System (SOGS), will suffice as an example. Comprising the computer instructions to command and control Hubble in orbit as well as to acquire and calibrate its captured data on the ground, all of SOGS amounted at launch to roughly 3 million lines of (mostly Fortran and C*) computer code... SOGS contains the equivalent of almost 2,000 man-years of computer programming written by a small army of a couple hundred individuals at the TRW Corporation and the Science Institute, none of whom knows precisely how the entire system works. In fact, Hubble's ground system exceeds in magnitude that of any computer program needed to operate any other known machine- at least in the civilian world...No human or group of humans could reasonably analyze the logic of all aspects of such a megaprogram as the abovementioned SOGS, which when first introduced into a realistic operating environment had a voracious appetite for mistakes. At least one NASA headquarters official, openly worried before launch about the project's ability to master the telescope's myriad operating modes, let alone to identify the potential for untested conflict among literally millions of interacting machine instructions, put it bluntly: "Frankly, my problems would be best solved if we plop the damn thing directly into the Atlantic."²¹

This quote demonstrates a single aspect of Hubble's structure which is by itself impossible for a single person "or group of humans" to fully have control over. Hubble was created through the interaction and cohesion of many different instruments and programs with similarly massive levels of complexity. The nature of big science programs necessitates the growing size and

²¹ Chaisson, *The Hubble Wars*, 52-53.

complexity of systems which ultimately overwhelm individual entities and agencies and require the successful interdependence of many different parts. Through the process of translation and simplification, the Hubble as a whole was initially represented as a failure, despite the successful development of myriad systems far and beyond the primary mirror and the other instruments which experienced issues. When an exceedingly complex and culturally encumbered program such as Hubble or the space shuttle does not live up to expectations, it becomes necessary in the public eye to isolate who or what is to blame, despite the inherent interconnectedness of network actors.

Callon argued that due to the complexity of these networks which form scientific objects, "in the absence of one ingredient the whole would break down."²² When an element within the complex networks of big science programs like Hubble or the space shuttle fail, the actors which had existed in the background are exposed to scrutiny as the existing translation disintegrates. Latour illustrates this process with the example of the space shuttle *Columbia*:

Take any object: At first, it looks contained within itself with well-delineated edges and limits; then something happens, a strike, an accident, a catastrophe, and suddenly you discover swarms of entities that seem to have been there all along but were not visible before and that appear in retrospect necessary for its sustenance. You thought the Columbia shuttle was an object ready to fly in the sky, and then suddenly, after the dramatic 2003 explosion, you realize that it needed NASA and its complex organizational body to fly safely in the sky... The action of flying a technical object has been redistributed throughout a highly composite network where bureaucratic routines are just as important as equations and material resistance. Yes, it is a strange space, that of a shuttle, that is just as much *in* the sky as *inside* NASA, but that's precisely the space—hard to describe and even harder to draw—that has been made visible by the deployment of network in my sense of the word.²³

Latour went on to argue that "the shuttle Columbia was not an object whose substance could be

defined, but an array of conditions so unexpected that the lack of one of them (a bureaucratic

²² Callon, "Sociology of an Actor-Network...", 23.

²³ Bruno Latour, "Networks, Societies, Spheres: Reflections of an Actor-Network Theorist," *International Journal of Communications* 5 (2011), 797.

routine) was enough to destroy the machine."²⁴ Although the particular problems which are determined to have caused big science catastrophes can often be isolated through a process of inquiry and investigation, whether it be icicles on the launch pad or an errant piece of foam insulation, the entire vast network of agencies, technology, and people, bear the implications of failure, although only a few entities experience the repercussions.

In the case of Hubble, the intersection of a nearly innumerable number of entities came together in order to represent one simplified scientific object. Hubble, and events which accompanied its development, were not singly the result of NASA or of Congress, but of many significant parts including: Marshall Space Flight Center, Goddard, Perkin-Elmer, Lockheed, the Space Telescope Science Institute, the administrators, scientists, astronomers, and engineers at all of these locations, the primary mirror, solar arrays, fine guidance sensors and other instruments, congressional committees on appropriations, senators and representatives, research universities vying for time to use the telescope, the European Space Agency, the space shuttle development and launches, space enthusiasts, and amateur astronomers, among others. The Hubble Space Telescope was created through an incredibly complex network of relationships and interactions which took place over the course of many decades, and to attempt to address a scientific object from this perspective "means acknowledging something of the unresolvable tension, the inseparable mixture, the impossible multiplicity, out of which intention and expertise must emerge."²⁵ The spherical aberration in Hubble's primary mirror was a relatively small malfunction which exposed the entire network of people and institutions involved in the program to the critique of the public. Although a small number of NASA officials and scientists had to

²⁴ Ibid., 798.

²⁵ Timothy Mitchell, "Can the Mosquito Speak?" in *Rule of Experts: Egypt, Techno-Politics, Modernity* (Berkeley: University of California Press, 2002) 53.

represent the entirety of the Hubble program when it was launched, and when it was perceived to have failed, they were only a small element in an incredibly complex story of how Hubble came to be, how it was flawed, and on what terms it was redeemed.

Chapter 2: Early History of Hubble and the Emergence of Big Science

Although it was not fully realized until the 1990's, the roots of Hubble's development could be traced back to the first telescopes which were developed in the 1500's. For the purposes of this analysis the rapid increase in technological development which accompanied World War II and the Cold War that followed was most significant in ushering in an era of big science and space science. Without the growth of military sponsored science, it is unlikely that NASA or the national space program as it is today would have come to be. The networks of development, administration, and science which formed the Hubble Space Telescope were embedded in the early establishment of the military and civil space programs.

The first satellites owe their technological catalyst to the development of the *Vergeltungswaffe zwei* (V-2) ballistic missile by Wernher von Braun in World War II. Von Braun's team of scientists in Peenemünde along with thousands of slave laborers developed the first man-made object to enter space. The V-2 rocket infamously caused more loss of life in its construction under the Nazi regime than in its successful deployment against Allied targets.²⁶ However, in the post-war United States the V-2 was repurposed in part to become the first sounding rocket to gather scientific data from beyond the ozone layer.²⁷ When the war in Europe ended in 1945, the U.S. Project Paperclip oversaw the extraction of many German scientists to the United States as well as several intact V-2 rockets and hundreds of train cars worth of German rocket parts. These scientists went on to work in a number of different applications; von

²⁶ Robert Smith, *The Space Telescope: A Study of NASA, Science, Technology, and Politics* (Cambridge: Cambridge University Press, 1989), 28.

²⁷ Todd Neff, *From Jars to the Stars: How Ball Came to Build a Comet-Hunting Machine* (Denver: Earthview Media, 2010), 12-13.

Braun extended his work on the V-2 rocket at White Sands Proving Ground in New Mexico under the auspices of the U.S. military.²⁸

At White Sands in the late 1940's and early 1950's, the V-2 rocket served as a host for many scientific experiments attempting to gather data on the upper atmosphere. Instead of explosives, the V-2 rockets were filled with instruments measuring everything from temperature to ultra-violet rays.²⁹ The V-2 could surpass the Karman line, which is generally accepted as the boundary of outer space; this meant its data gathering capacities soon surpassed that of the weather balloons which had previously been used. Corliss argues that post-Sputnik scientific satellites owed their existence "almost completely to military stimuli- hot and cold" although "the impact of Peenemünde on the development of scientific satellites was not in the concept of the idea-no one had yet suggested the unmanned, purely scientific satellite- but rather in the creation and refinement of supporting technology."³⁰ The V-2 rocket was the first step beyond earth's atmosphere, and although it's legacy during and after WWII remains largely defined by its military use, von Braun and his team would continue to improve upon the V-2 technology and future iterations would launch the United States' first scientific satellite and the first two American astronauts into space.

The intellectual possibility of a scientific satellite was conceptualized by the U.S. military as early as 1945 when the Navy Bureau of Aeronautics established the Committee for Evaluating the Feasibility of Space Rocketry, which "recommended launching a small satellite for scientific purposes."³¹ In 1946 the RAND Report, or "Preliminary Design of an Experimental World-Circling Spaceship" was published at the request of the U.S. military, whose branches had at that

²⁸ Willy Ley, *Rockets, Missiles, and Space Travel.* (New York: The Viking Press, 1958), 246.

²⁹ Neff, From Jars to the Stars, 12-13.

³⁰ William Corliss, *Scientific Satellites* (Washington D.C.: Office of Technology Utilization, NASA, 1967), 37-38.

³¹ Corliss, *Scientific Satellites*, 38.

time failed to come to agreement on a satellite program.³² This report was important to the development of the satellite program for a number of reasons; it concluded that satellites of all kind, military, scientific, or human occupied, were technologically feasible within a matter of years.³³ In addition to providing an overview of the technological and scientific data available, possible challenges, and cost assessments of hypothetical satellite vehicles, the RAND report also approximated the scientific and cultural impact of satellite development:

Though the crystal ball is cloudy, two things seem clear:

- 1. A satellite vehicle with appropriate instrumentation can be expected to be one of the most potent scientific tools of the Twentieth Century.
- 2. The achievement of a satellite craft by the United States would inflame the imagination of mankind, and would probably produce repercussions in the world comparable to the explosion of the atomic bomb.³⁴

The compilers of the RAND report were undoubtedly aware of their inability to predict the future, but their somewhat grandiose rhetoric was not necessarily that far off the mark. Although the development of satellites beyond Sputnik would be significantly more gradual than the instantaneous world-wide reaction which accompanied the use of the atomic bomb, the RAND report seemed to accurately foresee the array of potentially paradigm changing possibilities associated with the satellite concept.

The RAND report surveyed the possibility of many different types of man-made orbiting objects, including long-range ballistics. However, an appendix to the report and important astronomical treatise: "Astronomical Advantages of an Extra-Terrestrial Observatory" by Lyman Spitzer, Jr. focused specifically on the "new vistas of astronomical research" that could be

³² Corliss, *Scientific Satellites*, 38.

³³ "Preliminary Design of an Experimental World-Circling Spaceship", (Santa Monica: Douglas Aircraft Company, 1946), I.

³⁴ "Preliminary Design of an Experimental...", 1-2.

possible with an orbiting satellite observatory.^{35,36} Spitzer's paper enumerated the many benefits that an orbiting observatory could have over terrestrial observatories in terms of astronomical data about the universe.

Among other points, Spitzer notes the lack of atmospheric pollution and the constant presence in the space environment as aspects of an extra-terrestrial observatory, which would make it substantially more efficient and successful than terrestrial observatories. Spitzer's 1946 work effectively laid the groundwork for what would become the Hubble Space Telescope many decades later. Spitzer was confident in the profound cultural impact of a large orbiting observatory, stating:

...the chief contribution of such a radically new and more powerful instrument would be, not to supplement our present ideas of the universe we live in, but rather to uncover new phenomena not yet imagined, and perhaps to modify profoundly our basic concepts of space and time.³⁷

In this way Spitzer defines a purpose for this hypothetical large space telescope that is not subject to the fluctuation of politics or military need. Smith notes that "by separating the telescope's justification from particular astronomical questions" Spitzer made an argument for the telescope that was "timeless" in its scientific virtue.³⁸

Spitzer and a small community of other astronomers at this time were confident in the scientific value of a satellite observatory, however the broader scientific community had yet to be convinced of the feasibility of satellites in general. It would be a decade until the launch of Sputnik and the official start of the Space Race when satellite observatories would even be

³⁵ Lyman Spitzer, Jr. "Astronomical Advantages of an Extra-Terrestrial Observatory" *Preliminary Design of an Experimental World-Circling Spaceship*, Project RAND of the Douglas Aircraft Co. (1946). Rpt. In *The Astronomy Quarterly*, Vol 7, (1990): 131.

³⁶ Smith, *The Space Telescope*, 31.

³⁷ Spitzer, "Astronomical Advantages...", 139.

³⁸ Smith, *The Space Telescope*, 30.

considered as viable large-scale aspects of the space program. Spitzer's large satellite observatory had specifically scientific applications, however in the years leading up to the International Geophysical Year (IGY) the U.S. military was decidedly present in satellite development.

Initially deemed too expensive and complex, the progress of satellite technology combined with increasing Cold War pressure inspired the U.S. military to pursue the possibility of satellite reconnaissance in the late 1940's. The forthcoming IGY was intended to promote worldwide peaceful scientific discourse and study of the earth's environments; in honor of which President Eisenhower's Project Vanguard was meant to oversee the successful launch of a scientific satellite in 1957.³⁹

The impact of the successful launch of Sputnik I on the American political and cultural psyche cannot be overstated. The success of the Soviet launch implied a superior launch platform and more powerful rockets, implicit in which was the Soviet ability to launch nuclear weapons. The socio-cultural divisions between the United States and the Soviet Union amplified the gravitas of the event and the war over international prestige began in earnest. Exacerbated by the end of WWII and McCarthyism, pre-existing anti-communist beliefs fueled the hysteria surrounding the successful launch of Sputnik I and the utter failure of America's Vanguard I. Vanguard I, meant to be the United States' first satellite, exploded on the launch pad while being broadcast live on televisions across the country.^{40,41} Partially in reaction to the mounting pressures of the space race which the United States appeared to be losing, President Eisenhower was took steps to further integrate civil and military aerospace development.

³⁹ Ibid, 34.

⁴⁰ C. Peoples, "Sputnik and 'skill thinking' revisited: technological determinism in American responses to the Soviet missile threat." *Cold War History* 8, no. 1: 55–75.

⁴¹ Smith, *The Space Telescope*, 36.

When the Vanguard program seemingly faltered in 1957, the prestigious pressure of the Sputnik 1 success...caused the Secretary of Defense to announce on Nov. 8, 1957 that the Army was also to participate in the IGY satellite program. In making this decision, President Eisenhower permitted the Army to employ military rockets that had been specifically denied to the Vanguard Program because of the desire to keep the U.S. effort free from military overtones. On January 31st, 1958, the Army launched the first U.S. satellite, Explorer 1, using a Juno I rocket-a modified Jupiter rocket, which, in turn, was derived from the Redstone, which, to complete the chain, owed much to V-2 technologies.⁴²

The success of Explorer I was not enough to make up for the embarrassment of Vanguard and the national perception of Sputnik's success. Sputnik's success and the onset of the so-called Space Race led in part to the establishment of the National Aeronautics and Space Administration by President Eisenhower.

The 1958 National Aeronautics and Space Act clearly stated that NASA would be established under the guidelines that it be a civilian institution "devoted to peaceful purposes for the benefit of all mankind", shall contribute to a number of scientific objectives, and preserve the "role of the United States as a leader in aeronautical and space science."⁴³ The act specifically relegated all aerospace activity related to weaponry or national defense as the responsibility of the Department of Defense (DOD); it also maintained that "discoveries that have military value or significance" should be furnished to the DOD, and likewise non-military discoveries should be furnished to NASA. Although this original Space Act provided for a certain level of shared knowledge between NASA and the DOD, the two remained strictly distinct from one another.

This relationship between the "civilian" NASA and the DOD became increasingly convoluted and controversial as the Space Race wore on and the two agencies embraced larger

⁴² Corliss, *Scientific Satellites*, 45.

⁴³ United States Congress, "National Aeronautics and Space Act, as Amended through 1962", Rpt. *In An administrative history of NASA*, 1958-1963 by Robert L. Rosholt, (Washington DC: NASA, 1966), 1-2.

and more complex technological projects which often overlapped in many respects. Smith notes that:

Although NASA was created as a civilian agency, the new technologies that allowed men and machines to move around in space always had national security implications and applications...the separation of national security from civilian research and development of space technology would therefore be almost meaningless.^{44, 45}

The power dynamic between NASA, congress, and the DOD, had significant effects on technological development as well as on administrative strategies surrounding the national space program. The cultural and financial clout of the DOD had the ability to overwhelm the less charismatic civilian scientific projects of NASA scientists, opening the gates for legislative support and funding to be provided to programs with military and commercial incentives. The ideology of the space race entailed what was essentially a competition between the U.S. and the Soviet Union as a form of public and ideological spectacle. Wolfe argues that "for all their differences, leaders in both the Soviet Union and the United States agreed that massive displays of technological might were critical weapons in the international battle for hearts and minds."⁴⁶ Inherent in the formation of NASA was the need to "beat" the Soviets, which meant space strategy was always formulated with prestige and "space spectaculars" in mind.⁴⁷

Although the political pressures of the Cold War may have diverted attention away from a purely civilian scientific agenda, the launch of Sputnik I and proceeding space race "reshaped the thinking of politicians to such an extent that many old assumptions about the federal funding of space activities were promptly swept away. The usual rules on Capitol Hill lapsed for a time

⁴⁴ Smith, *The Space Telescope*, 36.

⁴⁵ William Hardy McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (Chicago: University of Chicago Press, 1982), 369.

⁴⁶ Audra J. Wolfe, *Competing with the Soviets: Science, Technology, and the State in Cold War America* (Baltimore: Johns Hopkins University Press, 2013), 6.

⁴⁷ Smith, *The Space Telescope*, 37.

as the legislators could hardly dispense money to NASA fast enough."⁴⁸ Without the political impetus, many NASA activities and related scientific programs would never have had the federal interest or funding to exist. The activities and success of NASA and the space program came to represent capitalism, democracy, and the American role in the world just as much as it represented science, which meant that from the beginning NASA activities would be closely monitored and assessed by congress to ensure NASA's successful representation of the American image in the world.

Although the intersection of NASA technology and national defense programs would be inevitable, Wolfe argues that:

It would be a mistake to fixate on military endeavors in understanding the role of science in the Cold War state. Starting with legislation that established the Atomic Energy Commission (AEC) in 1946, American scientists fought to maintain a separate arena for military science. The existence of such civilian institutions as the AEC, the National Science Foundation, and NASA were critical to both policymakers' and the public's ability to see science as an objective, transparent way of knowing that could transcend differences between interest groups.⁴⁹

The idea of science as a neutral method in which to pursue the fundamental questions about life, space, and time is a keystone of scientific inquiry and philosophy that has long been touted by scientists, included Spitzer in his landmark paper on space satellites. Science as a force transcendent of temporal issues is an ideal consistently present in scientific communities of discourse, but which has always been somewhat at odds with the reality of political, social, religious, and military interests. When the space race began in earnest in the 1960's, "this idea of 'open science' sat uneasily next to the reality of a research infrastructure that was largely backed by the state-particularly military-interests."⁵⁰ This intersection of pure scientific inquiry and the

⁴⁸ Smith, *The Space Telescope*, 37.

⁴⁹ Wolfe, *Competing with the Soviets*..., 5.

⁵⁰ Ibid.

political necessities of the Cold War provided the basis for rising fears about the nature of the industrial defense industry and the distortion of scientific practice.

In the shadow of President John F. Kennedy's inauguration, President Eisenhower's farewell speech was at the time largely overlooked. President Eisenhower coined the term "military-industrial complex" in the speech and expressed deep-seated concerns about the growth of military technology and the increasing role of the Federal government in determining the path of research and development. Eisenhower warned against the "potential for the disastrous rise of misplaced power" due to the increasingly "formalized, complex, and costly" concentration of research and development at the federal level. He noted that:

Partly because of the huge costs involved, a government contract becomes, virtually, a substitute for intellectual curiosity. The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present—and is gravely to be regarded.⁵¹

Eisenhower feared that the supposedly altruistic neutrality of scientific pursuit would be corrupted and eclipsed by the rising power of defense industries. Although his views represented a somewhat idealized conception of science, he was accurately aware that the institutional role of science was changing and would have cultural, political, and technological consequences throughout the Cold War era and beyond.

In the same year as President Eisenhower's farewell address, Alvin Weinberg, director of

the Oak Ridge National Laboratory, acknowledged the increasing presence of large-scale

scientific projects and argued:

When history looks at the 20th century, she will see the science and technology as its theme; she will find in the monuments of Big Science—the huge rockets, the high-energy accelerators, the high-flux research reactors—symbols of our time just as surely as she finds in Notre Dame a symbol of the Middle Ages...We build our monuments in the

⁵¹ Dwight D Eisenhower, "Farewell Speech, reading copy" (1960), Received from: http://www.eisenhower.archives.gov/research/online_documents/farewell_address/Reading_Copy.pdf (Accessed, Dec, 2013), 1-19.

name of scientific truth; they build theirs in the name of religious truth; we use our Big Science to add to our country's prestige, they used their churches for their cities' prestige.⁵²

Central to Weinberg's analysis was the risk that the growth of big science would become enormously expensive and that it could threaten the more benevolent and pure scientific pursuits which serve to enlighten humankind in some way or another. The introduction of big science as a new technological trend opened the door to criticism of large government run programs in favor of supposedly less corruptible "small" science. Big science in the national space program began largely with Apollo. Although Apollo was ultimately considered one of, if not the most efficient and successful example of big science in American aerospace, the questionable justification for the program was not lost on contemporary (or future) observers. Suggested partly by his use of religious monuments as a metaphor, Weinberg suggests that there are ethical problems with the combination of science and the state.

Weinberg feared that big science turned scientists into lobbyists, scientific peer-review into media-driven popularity contests, and academic lecture halls into congressional committee rooms. Weinberg acknowledged the inevitability of big science but he lamented the transition to overbearing administrative systems and the proclivity towards "Big Science spectaculars" rather than more fundamental scientific questions. This tendency towards prestige-driven science versus more academically productive scientific projects was embodied in the Apollo program's emphasis on manned spaceflight and President Kennedy's goal to go to the moon.⁵³

When the Soviets successfully launched Yuri Gagarin into orbit on April 12th 1961, the United States was once again reminded that it was falling behind in the space race. Emphasizing the importance of maintaining international prestige, President Kennedy provided the political

⁵² Alvin Weinberg, "Impact of Large-Scale Science on the United States," *Science* 134, no. 3473 (July 1961): 161. ⁵³ Ibid, 2.

justification and funding to make Apollo the United States' most successful manned space program. Roger Launius, senior curator for the Smithsonian Air and Space Museum, has written quite extensively on NASA history and argues that the Space Race was always driven more by politics than by science and technology. Launius argues that President Kennedy's famous speeches in 1961 and 1962 have in some ways been misconstrued throughout time in a way that obscures the real historical and political issues at stake during the time period.⁵⁴ Rita Koman, of the Organization for American Historians, makes a similar argument and points out that "[Kennedy's] actions...played on American fears of communism and implicitly inferred that the Eisenhower administration had not done enough to meet the Sputnik challenge."⁵⁵ The Apollo program is one of the best examples of what large-scale scientific projects can accomplish in a very short amount of time, given the budget is generous and the mission goals are clearly defined and publically supported.

The Apollo program and its culmination with men landing on the moon has had the most indelible and profound effect on the American perception of the space program. NASA was provided an unprecedented amount of funds and the technological and intellectual resources were all in place to pursue an unprecedented goal and take command of the space race. Tied to the significant increase in NASA resources, smaller science programs such as the Orbiting Astronomical Observatory (OAO) program were able to thrive throughout the 1960's. Although the Kennedy administration stressed an emphasis on programs that would be the most prestigious, namely manned spaceflight, NASA administrator James E. Webb fought to maintain a well-balanced space program that looked towards future goals as much as possible. The OAO

⁵⁴ Roger Launius, "Kennedy's Space Policy Reconsidered," Air Power History. (2003): 17-29.

⁵⁵ Rita Koman, "Man on the Moon: The U.S. Space Program as a Cold War Maneuver" *OAH Magazine of History* 2, no. 2 (1994): 42-50.

satellites provided the first ultra-violet light data, and although two out of four missions failed, the program effectively laid the groundwork for what would become the Great Observatories program and the Hubble Space Telescope.⁵⁶

Unlike the fiscally conservative views of President Eisenhower before him, Kennedy was prepared to commit substantial resources to the manned spaceflight program. NASA's budget would never be higher than in the mid 1960's at the height of the Apollo program, accounting for approximately 4.5% of the entire federal budget at its highest point in 1963 (compared to approximately .5% presently).^{57, 58} Despite the cultural achievement and historical significance of the Apollo program, it was not the most scientifically viable direction for the space program to take. Kennedy's decision to support the manned spaceflight program was not recommended by his science advisors, who argued that "NASA would be better off investing in robots and unmanned probes…the first U.S. satellite, *Explorer I*, scored an impressive scientific achievement by revealing the existence of the Van Allen radiation belt, and it had done so without putting lives unnecessarily at risk."⁵⁹ The technological, political, and cultural risk of successfully completing a manned moon-landing was immense, as historian Audra Wolfe put it: "the only thing worse than being the second nation to put a man on the Moon would be to kill a series of charismatic astronauts in the process."⁶⁰

Three astronauts, however, were killed in the process of preparing for a potential moon landing. In early 1967, Gus Grissom, Ed White, and Roger Chaffee burned to death in a practice Apollo command module while training on launch pad 34 at Cape Kennedy. Grissom was one of

⁵⁶ Smith, The Space Telescope, 34-46.

⁵⁷ United States. Dept. of Management and Budget. *Table 4.1 Outlays by Agency: 1962-2018*. Received from: http://www.whitehouse.gov/omb/budget/Historicals/ . (Accessed, Nov. 2013).

⁵⁸ Wolfe, *Competing with the Soviets*..., 94.

⁵⁹ Ibid, 93.

⁶⁰ Ibid, 94.

the original Mercury 7 astronauts, was the second man in space, and was a popular choice to be the first person to step on the moon.⁶¹ The astronauts had expressed concerns about the design of the capsule beforehand and it was ultimately determined that the tragedy was



Image 3: (Left to right) Gus Grissom, Ed White, and Roger Chaffee, first American casualties of the space race. 1967. Source: NASA.

caused by a number of preventable flaws in the design of the command module and the training procedures.⁶² The astronaut's widows eventually received settlements from North American Rockwell, the contractor of the Apollo module, and NASA was intensely scrutinized and criticized by congress. Despite the loss, the Soviet threat and the imminent possibility of the moon landing facilitated NASA and the public's recovery from the tragedy. Testing continued and the Apollo spacecraft was flight ready and orbiting the moon by the next year. The resounding technical achievement and cultural impact of the moon landing was sufficient enough in part to palliate the deaths that occurred in 1967, however, the recovery process would not be so straightforward in the wake of the *Challenger* and *Columbia* tragedies.

The technological and philosophical grandeur of successful celestial travel provided only a brief respite from changing cultural trends at the end of the 1960's which increasingly saw the space program as little more than a "distraction from the United States' limited achievements in

⁶¹ Deke Slayton and Michael Cassutt, *Deke!: U.S. Manned Space from Mercury to the Shuttle* (New York City: St. Martin's Press, 1994) 223, 234.

⁶² United States Senate. Committee on Aeronautical and Space Sciences. *Apollo 204 Accident with Additional Views* (Washington, D.C.: U.S. Government Printing Office, 1968).

conquering poverty, racial inequality, and urban violence."⁶³ The American public gradually became acclimated to the climate of the Cold War and turned their attention towards more immediate social issues, increasingly de-emphasizing the cultural importance of the space program.

This cultural shift was evident in the re-evaluation of the space program by President Nixon's administration in the early 1970's. The Apollo program puttered to a relatively quiet close despite five more successful lunar landings and President Nixon approved the development of the space shuttle in 1972. The space shuttle was chosen after the rejection of NASA's initially proposed plans for a Mars mission and an orbiting space station because of high costs.⁶⁴ Other scientific space missions, such as the large satellite observatory and the space shuttle, would compete with each other for funding allocation throughout the 1970's. Unlike the relatively swift development and realization of Apollo's mission goals in less than a decade, the space shuttle and the large satellite observatory program would not be realized for the next 20 and 30 years, respectively.

As America's role in the world changed, Americans and the international community began to question the quest for prestige as well as technological and cultural dominance. Big Science in the American space program came to be associated with increasingly antiquated imperialist ideals and militarism,

The Apollo program was designed to display and ensure American dominance; much of the underlying research was classified; and the majority of American space efforts were at least as much about producing missiles and spy satellites as they were about creating new scientific knowledge. The pretense of civilian leadership gave American imagemakers the possibility of having it both ways.⁶⁵

⁶³ Wolfe, *Competing with the Soviets*..., 103.

⁶⁴ Smith, *The Space Telescope*, 124.

⁶⁵ Wolfe, *Competing with the Soviets*..., 5.

In the context of socio-economic and political changes in the second half of the twentieth century, the mere "pretense" of civilian leadership was no longer enough. The military and the space program had developed an intimate partnership, and as a result the public questioned the neutrality, necessity, and relevance of the space program.

Chapter 3: Impact of the Space Shuttle

Space spectaculars like the moon landing provide justification for scientific research because of their visible and tangible results which bolster American cultural narratives of overcoming odds and crossing frontiers. Big science provided the means to go to the moon, however, the cultural and political changes which began in the late 1960's such as the civil rights and anti-war movements shifted national priorities enough to significantly strip funding away from the space

program. Despite the winding down of the space race in 1975 with the joint Apollo-Soyuz test program between the U.S. and Russia, space spectaculars and the desire for international prestige still weighed heavily on the space program. NASA attempted to meet the expectations of Apollo with equally ambitious and scientifically compelling programs, however, it became clear that the public support and political funding which allowed the extensive program to function would not be so easily accessible in the 1970's and 1980's.



Image 4: Apollo-Soyuz Test Project, 1975. Source: Time Magazine Archive.

An article written in 1969 by George Mueller, then Associate Administrator of NASA, illustrates the incredible optimism and high expectations which characterized the perception of the space program after the moon landing:

This day man's oldest dream is made a reality—this day the ancient bonds tying him to the earth have been broken. Apollo has given us a new freedom. With the achievement of the first manned landing on the surface of the moon, we have accomplished the most momentous feat in the long history of man. The triumph of Apollo is nevertheless only the beginning—it has given us the confidence to dream those impossible dreams...For men of all nations, and of all stations, Apollo is a portent of progress, a benign symbol of their ability and of their civilization.⁶⁶



Image 5: Artist Representation of Space Shuttle, 1969. Source: The New York Times.

This article, published in the New York Times, goes on to enumerate the multitude of space programs that would likely prosper throughout the 1970's. At the time it was considered technologically feasible that by the end of the 1970's there would be a near constant human presence on the

moon to conduct research, an orbiting space station that could conduct a wide variety of research including a "high energy cosmic ray and high energy physics laboratory," and a low-cost, reusable space vehicle which would allow travel not only to the moon, but to planets.⁶⁷ This enthusiasm was rapidly curtailed by political and cultural changes which made it clear that the same resources and support which had made Apollo so successful would not be available in the same way for future programs.

The percentage of the federal budget which was allocated to NASA steadily fell throughout the 1970's and into the 1980's, hovering at approximately .8%.⁶⁸ President Nixon began in early 1970 with a 12.5% budget cut which meant the closing of facilities and termination of thousands of NASA jobs. Despite these cuts and schedule delays, it was still predicted that the shuttle would be operable by the late 1970's and a manned mission to Mars

⁶⁶ George E. Mueller, "In the Next Decade: A Lunar Base, Space Laboratories and a Shuttle Service," *The New York Times* 21 July, 1969.

⁶⁷ Ibid.

⁶⁸ United States. Dept. of Management and Budget. *Table 4.1 Outlays by Agency: 1962-2018*. Received from: http://www.whitehouse.gov/omb/budget/Historicals/ . (Accessed, Nov. 2013).

would occur in the 1980's.⁶⁹ The choice of the space shuttle program was critiqued from very early on as economically unfeasible and of questionable scientific utility. Liberal democrats in the Senate including William Proxmire and Walter F. Mondale advocated for amendments in 1971 which would have completely cut the shuttle program and created a cap on military spending. Mondale argued for a reprioritization of federal spending and asked whether the space shuttle was "more important than safe streets, clean air and water and freedom from deadly disease?"⁷⁰ The amendments were ultimately struck down but they reflect the consistent political vulnerability that characterized the shuttle program from the beginning.⁷¹ Mondale went on to serve as the vice president under Jimmy Carter from 1977 to 1981, an administration which put little priority on the space program. A contemporary reporter lamented the state of the space program during the late 1970's: "Gone are the ecstatic calls from the Oval Office to the surface of the moon and the program was rarely, if ever, mentioned in last year's [1976] Presidential campaign. President Carter made a cursory 30-minute inspection trip to NASA headquarters about two months ago...but he did not even mention the future of the space program."⁷² Although many large and costly NASA programs were being developed throughout the 1970's, many did not come to fruition and were not situated in the public eye until the 1980's and later.

Having successfully reached the moon and lacking a powerful new directive, the state of the U.S. space program was drastically changed from the 1960's to the 1970's. Many people were left in the dark and with unanswered questions regarding the direction of new space based

⁶⁹ Richard Lyons, "12.5% Slash in NASA Funding Will Force Sharp Program Cut." *The New York Times*, Feb. 3rd 1970.

⁷⁰ John W. Finney, "Senators Reject Arms-Fund Cuts," *The New York Times* 30 June, 1971.

⁷¹ John Noble Wilford, "Opposition in Congress to Space Shuttle Likely," *The New York Times* 6 Jan 1972.

⁷² Richard Lyons, "US Space Program Lags Because of Lack of Interest and Money," *The New York Times* 13 April 1977.

programs such as the shuttle. Brian O' Leary, a scientist, author, and astronaut, predicted in 1971 that the initial budget appropriation for the shuttle program would be

Merely the tip of the iceberg of what might become one of the nation's costliest boondoggles of all time... [The shuttle would be economical] only if there were more than one flight per week for several years, perhaps decades. In fact, NASA proposes sixty flights per year, of which thirty are earmarked for defense. Why should NASA spend money for a defense project, a very questionable one at that? Inevitably, we are left with a hardware system looking for something to do, rather than a pre-existing motivation to use the hardware.⁷³

He believed that in the light of "more pressing domestic problems" an unmanned spacecraft would be safer, cheaper, and a more efficient way to collect scientific data. O' Leary expressed concern that the popular emphasis on manned spaceflight was leading the space program in a direction which was justified more by the romanticized past than by scientific productivity. Many other scientists and officials, including Wernher von Braun, were openly wary of the high costs of the space shuttle and questioned the government's willingness and ability to provide adequate funding.⁷⁴ Although the space shuttle program failed to meet budgetary restraints or scheduled deadlines, there were still very successful scientific programs which took place in the 1970's. President Nixon's plan for a "Grand Tour" of the solar system conducted by space probes was probably, in the long term, one of the most productive and successful NASA programs.⁷⁵ *Voyager* 1 and 2 launched right on schedule in 1977 and have provided a nearly unmatched amount of scientific data and traveled farther away from Earth than any other manmade object. The *Voyager* missions cost NASA approximately \$900 million over the course

⁷³ Brian O'Leary, "The Wild Blue Space Shuttle," *The New York Times* 30 Jan, 1971.

⁷⁴ Harold Schmeck, "Fund Lack Cited in Space Project," The New York Times 1 April, 1970.

⁷⁵ James M. Naughton, "Nixon Asks Start of a "Grand Tour" of Planets in '77," New York Times 8 March, 1970.
of nearly four decades of functionality, while the space shuttle program was already over budget by \$1 billion (for a total of approximately \$6 billion) before any launches had occurred.⁷⁶

In the early 1970's, the space shuttle and the Large Space Telescope program (which became Hubble) were tied together to make a more appealing bid to congress. The NASA Offices of Manned Space Flight and Space Science argued that the reusable nature of the space shuttle would make payloads such as the Large Space Telescope (LST) more flexible and costefficient.⁷⁷ The space shuttle was approved by President Nixon in 1972. In 1974, with money already spent on the Mars Viking program and Skylab, the congress House Appropriations Subcommittee suggested that a "less expensive and less ambitious project be considered as a possible alternative" to the Large Space Telescope Program. The space shuttle had a somewhat easier time receiving initial funding compared to the LST because the idea of a reusable and manned space vehicle was immediately appealing to the public. Historian of science and technology at the University of Alberta, Robert Smith wrote that "because it was, in the agency's view, far and away its most important program- the one that underpinned all its space activitiesthe shuttle took the bulk of the money the agency was receiving for design and development."⁷⁸ Despite its early critiques, the Space Shuttle Program was more relatable, more charismatic, and easier to justify politically than other specifically scientific and civilian NASA programs.

As the Large Space Telescope program almost lost all of its congressional backing in 1974, NASA officials, astronomers, and contractors came together to bolster political support for the program. Contractors such as Perkin-Elmer, which had begun studies on the Optical Telescope Assembly, as well as McDonnell Douglas and Lockheed were able to lobby

⁷⁶ "Voyager Fact Sheet," Jet Propulsion Laboratory, NASA. Received From:

http://voyager.jpl.nasa.gov/news/factsheet.html (Accessed 23 Feb, 2014).

⁷⁷ Smith, *The Space Telescope*, 120.

⁷⁸ Ibid, 283.

politicians in a way that civil service employees at NASA could not. Some astronomers, such as Lyman Spitzer, directly engaged themselves in lobbying for the LST. At the time it was unprecedented for scientists to engage in politics as they did not yet have a professional lobbying organization and it was largely seen as "beneath the dignity of science."⁷⁹ This attitude was illustrative of how scientific practice was often elevated to a higher moral standard by practitioners and non-scientists alike, and how the scientific and political realms could become alienated from one another as a result of their predisposed discourses. LST supporters also approached what would become the European Space Agency to partake in the project, primarily as a way to unburden themselves of some of the development costs. The design of Hubble was reassessed in a way which would allow international collaboration, fit an increasingly limited budget, and would satisfy the scientific community, NASA, congress, international interests, and contractor interests.

Department of Defense interest in the shuttle was also an important factor in how time and funding within NASA was allocated throughout the 1970's and 80's. Hubble was developed from the beginning to be dependent on the shuttle, and the shuttle was dependent on the military's need to deploy similarly large, complex, and expensive classified satellites. Many military reconnaissance missions, including the launch and deployment of the massive KH-11 and KH-12 "keyhole" spy satellites which were "capable of reading license plates in the Kremlin,"⁸⁰ were developed as the Hubble was to be heavily reliant on manned space shuttle missions. A 1984 article in the New York Times argued that

The history of the American space program is replete with tension between those who would preserve space as a frontier for scientific exploration and those who would seize it as a soldier's ultimate high ground. But the shuttle project has gradually left the National

⁷⁹ Smith, *The Space Telescope*, 125-128.

⁸⁰ William Safire, "Spying on Pretoria," The New York Times 16 April, 1979.

Aeronautics and Space Administration a junior partner to the Defense Department in budgetary, technological and political strength.⁸¹

Without the military interest in the shuttle as a way of deploying defense related satellites, establishing a military astronaut presence, and generally enabling U.S. national security interests from space, NASA would not have received the same level of executive and military support for the shuttle program.⁸²



Image 6: U.S. Space Budget, 1971-1990. Source: Office of Management and Budget, "Aeronautics and Space Report to the President," 1989.

President Reagan's plan to pursue the Strategic Defense Initiative further emphasized the

military's role in space and the military's appropriation of the budget,

By the early 1980's, moreover, the Pentagon's space budget had overtaken NASA's space budget. According to G.A.O. [Government Accountability Office] analyses, the Defense

⁸¹ Wayne Biddle, "Military's Role in Space," *The New York Times* 21 Dec, 1984.

⁸² Kathy Sawyer, "Military Payloads Dominate New Schedule for Shuttle," The Washington Post 4 Oct, 1986.

Department's 1983 budget for space projects totaled \$8.5 billion in unclassified funding, of which \$581 million was related to the shuttle. NASA's entire budget request for the fiscal year 1983, by comparison, was \$6.6 billion, of which \$3.4 billion went to the shuttle.⁸³

Although never fully proven to be within the realm of scientific possibility and criticized as a reckless political maneuver, the Strategic Defense Initiative nevertheless consumed billions of federal dollars throughout the final decade of the Cold War. ⁸⁴ Although the military and civil aerospace programs were hypothetically intended to be mutually beneficial to each other in terms of shared technological knowledge, the relationship was often unbalanced to NASA's detriment. Hubble experienced problems with its solar arrays prior to the first 1993 servicing mission, and Chaisson asserted that

The military, long aware of the adverse effects of the flimsy lightweight arrays, had redesigned them to be more robust and compact, above all less susceptible to jitter. And, once again, they were apparently unwilling or unable to tell the civilian-based *Hubble* project...Sometimes I think the intelligencers were trying to make NASA look not just bad but foolish.⁸⁵

Solar panels were likely not the only valuable technological asset which essentially "sat on a shelf at Lockheed...because they "officially" did not exist."⁸⁶ Although it is difficult to assess the extent to which the military may have paralleled or surpassed Hubble and other civilian technology, the growth of appropriations for defense related aerospace development quickly began to surpass that of the civilian program.

Whatever the size of the budget, the ability of both civil and military elements of the space program to stay within their fiscal guidelines was made increasingly difficult with every failure or delay. \$4 billion was spent at Vandenberg Air Force base in California to establish a

⁸³ Wayne Biddle, "Military's Role in Space," *The New York Times* 21 Dec, 1984.

⁸⁴ Chaisson, *The Hubble Wars*, 53.

Wolfe, Competing with the Soviets, 128-130.

⁸⁵ Chaisson, *The Hubble Wars*, 341.

⁸⁶ Ibid, 357.



Image 7: Space Shuttle Enterprise and Facilities at Vandenberg. Source: U.S. Air Force.

west coast shuttle launch facility "designed to place clandestine military satellites into orbit."⁸⁷ The shuttle was initially intended to be the exclusive launch vehicle for high priority military missions, however, the dependability of the space shuttle was immediately called into question after

the *Challenger* tragedy and ultimately no space shuttles ever launched from Vandenberg. Following *Challenger*, subsequent shuttle schedule delays, as well as Titan and Delta launch failures in 1986, the military's capability to launch defense related payloads was put under significant stress.⁸⁸ As a result, in the years following *Challenger*, military missions took priority over scientific and commercial projects and consistently accounted for a significant portion of shuttle payloads.⁸⁹

Public detachment from the space program and mistrust in NASA reached a peak after the widely viewed *Challenger* disaster in 1986. "People I've talked to today compare it to the

⁸⁷ Robert Lindsay, "Military is Pushing its Shuttle Program Amid Rising Debate," The New York Times "Vandenberg Space Shuttle Launch Complex," *United States Air Force Fact Sheet*, Sept. 1981, p. 1.

 ⁸⁸ Jon Connel, Mark Hosenball, & Peter Wilsher, "The Right Stuff Goes Wrong," *The Sunday Times* 11 May 1986.
⁸⁹ "Summary of Shuttle Payloads and Experiments," *NASA History Program Office*. Retrieved from: http://history.nasa.gov/pocketstats/sect%20B/P&E.pdf (Accessed: Feb. 24th, 2014).

day Kennedy was shot," said a Houstonian interviewed the day of the tragedy.⁹⁰ The American public was dealt a devastating blow when President Kennedy was assassinated, although the hope and idealism he inspired lived on in part through his political successors. Still considered a father of the space program, Kennedy's goals were cited by President Johnson throughout his tenure in order to bolster support for the Apollo program. Although the space shuttle flew for many more years following the *Challenger* disaster, the program never met the original expectations or fully recaptured the imagination of the American public.

The O-ring failure which ultimately caused the *Challenger* explosion was found to have been entirely preventable in hindsight, much like the electrical and mechanical issues which led to the *Apollo I* tragedy in 1967. Although the deaths of the Apollo astronauts were redeemed at least in part by the moon landing two years later, the deaths of the *Challenger* (and *Columbia*) astronauts remain a testament to the disappointment and tragedy of the space shuttle program. Although President Reagan's speech following the incident was a powerful invocation of the pioneering spirit of the American space program which harkened back to the Apollo era, a newspaper article published the day following *Challenger* illustrated the profoundly different affect this tragedy had on the American public:

The sense of national catastrophe is inevitably heightened in a television age, when the whole country participates in it. A first hint of the power of the electronic media to bring disaster directly into the living rooms came with the radio broadcast of the explosion of the zeppelin Hindenburg in 1937; but that was nothing compared with the pictures this morning of the space shuttle exploding, disintegrating and etching chaotic, sickening contrails against the blue sky.⁹¹

The continuing effect that *Challenger* had on the space program and on the public cannot be overstated. In an article reflecting on the end of the space shuttle program 25 years later in 2011,

⁹⁰ Robert Reinhold, "The Shuttle Explosion; at Mission Control, Silence and Grief Fill a Day of Horror Long Dreaded," *The New York Times* 29 Jan. 1986.

⁹¹ R.W. Apple, Jr. "President as Healer," *The New York Times* 29 Jan, 1986.

it was still remembered that "Buck Roger's dreams died that day" and "they died a second death on February 1st, 2003, when the *Columbia* broke apart on re-entry." ⁹²

Although the Rogers Commission Report into the *Challenger* disaster was able to define the incident as the result of an O-ring failure and flawed management decisions at NASA, it was less successful in enumerating the combination of historically rooted technical, bureaucratic, and political decisions and actions which likely contributed to the eventual physical failure which occurred on the launch pad.⁹³ Additionally, as the 1986 New York Times article above illustrates, the advent of other technologies especially that of mass visual media made the event exponentially more impactful than aerospace tragedies of the past. It was difficult to assess in a report how the accumulation of interactions within the space shuttle's vast developmental network influenced the *Challenger* failure, however, after *Columbia* was destroyed in 2003 many blamed the failure of the Rogers Commission in the 1980's to adequately identify and respond to the systemic issues behind the tragedy. The investigators into the *Columbia* disaster made definitive efforts to delve deeper into the underlying issues which resulted in the tragedy, including the culture of inadequate risk assessment in the space program, the "politicization" of NASA, and "strict budget limits" imposed simultaneously with grandiose program proposals.⁹⁴

Originally touted as a "space bus" which could fly 50-60 flights per year, the space shuttle flew successfully 132 times over the 30 year span of the program.⁹⁵ The question of risk undoubtedly arose as Hubble was developed to work in coordination with the space shuttle, the only orbiting telescope to do so. Eric Chaisson asked of Hubble's deployment: "Why would our

⁹² Dennis Overbye, "As Shuttle Era Ends, Dreams of Space Linger" The New York Times 4 July 2011.

⁹³ "Report of the Presidential Commission of the Space Shuttle Challenger Accident, Volume 1," *Rogers Commission Report.* (Washington DC: 1986).

⁹⁴ "Report of Columbia Accident Investigation Board, Volume 1," *Columbia Accident Investigation Board*. (Washington DC: 2003).

⁹⁵ U.S. Senate. Committee on Appropriations. *Problems at NASA* 101st Congress, 2nd session, (Washington, D.C.: U.S. Government Printing Office, 1991), 2.

technological society risk astronauts' precious lives to launch and deploy a robot that could otherwise have been lifted more cheaply and more effectively into orbit by means of an unmanned, expendable rocket?⁹⁹⁶ This and other questions unfortunately have come to define the very ambiguous legacy of the space shuttle.

⁹⁶ Eric J. Chaisson, *The Hubble Wars: Astrophysics Meets Astropolitics in the Two-Billion Dollar Struggle over the Hubble Space Telescope* (New York, N.Y.: Harper Collins, 1994), 13.

Chapter 4: "The Trouble with Hubble"⁹⁷

Originally intended to be launched as early as 1986, Hubble experienced delays along with the rest of the space program. The space shuttle *Discovery* launched Hubble into orbit in April of 1990 and it was at the time the largest and most



Image 8: Galaxy M100 Before and After STS-31, the First Hubble Servicing Mission in 1993. Source: NASA.

Unfortunately, soon after deployment a spherical aberration in the primary mirror of Hubble was revealed much to the consternation of politicians, the public, and all who had developed Hubble over the past several decades. The Hubble optical flaw was eventually determined to be primarily the fault of contractor Perkin-Elmer.⁹⁸ In short, Perkin-Elmer polished the primary mirror too flat which distorted the telescope's ability to focus and resulted in blurry images. Although the spherical aberration itself may have been identified as a single physical error, it likely resulted from a compounding of interconnected issues. Whatever the cost oversights, management issues, inaccurate calculations, and regulation failures which contributed to the Hubble flaw, the popular reaction to it was amplified by other issues within the space program. To many politicians, Hubble was not a solitary event but rather a representation of long term failures within the national space program.

complex civilian scientific instrument to utilize the space shuttle's generous cargo bay.

In the Hubble Space Telescope Flaw hearing before the Committee on Science, Space, and Technology in 1990, the Democratic Chairmen Robert Roe began with a call for his fellow politicians to recognize the role congressional appropriations play in civil space programs:

⁹⁷ George Johnson, "The Trouble with Hubble," The New York Times 1 July 1990.

⁹⁸ Lew Allen, "The Hubble Space Telescope Optical Systems Failure Report." NASA (1990).

For years, Congress, in the fatality of its policies, has been nickel and diming NASA, and I think that has had a consequence. The decision not to fully test the mirrors was made in large part for budgetary reasons. I think it is high time that Congress realized that large, costly projects cannot be run on a shoestring, and they can't be just be run from appropriation to appropriation.⁹⁹

Chairmen Roe advocated for "self-examination" by Congress, however many of his peers argued

for an examination of NASA's managerial abilities, NASA's efficient use of allocations, the

quality of contracted work, and the relative value of scientific data and the Hubble program.

Although the Hubble flaw drew into question the network of agencies and scientists which had

contributed to Hubble's development, NASA's status as a network translator in many ways

protected these other elements from blame.



Image 9: Simplified Hubble Organizational Structure and Project Responsibilities. Source: Smith, The Space Telescope, 227.

⁹⁹ U.S. House of Representatives. Committee on Science, Space, and Technology. *Hubble Space Telescope Flaw* 101st Congress, 2nd session, (Washington, D.C.: U.S. Government Printing Office, 1990), 3.

NASA's role as the representative for Hubble meant that Hubble's performance in turn represented NASA and the space program more than anything else. To most politicians, the media, and the public, the role of Perkin-Elmer or of Lockheed mattered very little compared to the implications of a potentially unfixable flaw not just on Hubble but in the national space program. Callon wrote that "the translator expresses their desires, their secret thoughts, their interests, their mechanisms of operation...for what is true for human entities, whether they be collective or individual, is also true for the other elements that constitute an actor-world."¹⁰⁰ NASA's cultural history is ingrained with notions of space spectaculars and American exceptionalism, and therefore Hubble was advertised in such a way which reflected these aggrandized standards. Rather than be represented to the public in a way which would highlight the complexity and power as well as the riskiness and vulnerability, NASA endorsed Hubble as something which would make groundbreaking discoveries about the nature of the universe and be a monument to human scientific progress. Although this may have been true in the long run, NASA misrepresented the multi-faceted nature of Hubble and damaged its own reputation in the long term. The high level of criticism encountered by NASA is in many ways characteristic of big science and the incredible difficulty inherent in translating a scientific program which encompasses multitudes of technical, political, and economic networks.

In response to the dramatic public and political reaction to the flaw, Chaisson argued that "honest and open appraisals of Hubble's commissioning problems might have resulted in a more balanced discussion of the aberration issue and of its possible solutions."¹⁰¹ He goes on to argue that the way in which NASA dealt with or represented Hubble's flaw only exacerbated the

¹⁰⁰ Callon, "The Sociology of an Actor Network..." 25.

¹⁰¹ Chaisson, The Hubble Wars, 186.

situation to their detriment. Chaisson described a 1990 press conference in which NASA addresses the aberration:

In their opening remarks, the emotionally drained officials immediately moved to raise the ante, even before Hubble's ills were explained clearly, by announcing that NASA was impounding the relevant design records, data logs, and polishing machines of Hughes Danbury and was convening a formal Board of Inquiry to investigate the origin of the mistake—all of which had the effect of transforming a technical problem into a social crisis...The prospect that there would, after all, be no pictures from Hubble hit the media hard; they had become wrapped up in this science project like no other in history.¹⁰²

The media and the public were likely wrapped up not only in the idea of pictures from Hubble but in the idea of big science living up to expectations and reinvigorating a stumbling national space program. Upon the announcement of Hubble's flaw it was not enough for the civil space agency to plan for a fix or promise to investigate the root causes of the problem. "The space agency was about to undergo a 'NASA-bashing' the likes of which it had not experienced."¹⁰³

Congress attempted to shift blame between budgetary, cultural, and technical elements of NASA's structure in order to explain how such an advanced and seemingly elite program could fall victim to what scientists considered a relatively simple surface flaw on an otherwise fully functioning instrument, and what politicians considered a multi-billion dollar catastrophe. George Brown Jr., a liberal Democrat, expressed his agreement with Roe on NASA's budgetary constraints, connecting it explicitly to the space shuttle failures in the process:

Hubble may yet be another example of what happens when we run highly complex research and development programs on tight-fisted budgets. As with the space shuttle *Challenger* accident, we may have been penny wise and pound foolish. Though some may want to point the finger at NASA failing to require an end-to-end test of the Hubble space telescope optical system, NASA may have been constrained by budgetary pressures to keep the cost of the program low...Instead of causing us to point fingers, Hubble's troubles should prompt a constructive and necessary debate on how exciting space exploration projects we now envision can be carried out without repeating the mistakes of the past.¹⁰⁴

¹⁰² Chaisson, The Hubble Wars, 187.

¹⁰³ Ibid.

¹⁰⁴ U.S. House of Reps, *Hubble Space Telescope Flaw*, 3-4.

More than other incidents, the loss of space shuttle *Challenger* initiated not only investigations into NASA but also introspection by politicians about the standing of the space program.

The national space program was and is subject to the assessments made by politicians as to whether or not certain programs do enough "good" for American people to justify annual budget allocations. Ideas of what is and is not "good" invariably varies greatly between different politicians and different scientists, but the Challenger tragedy left an indelible mark in the minds of everyone who witnessed it and had consequences that reverberated throughout the entire program. Challenger made possible the idea that the successful space program of the 1960's was an anomaly, and put simply, many politicians and much of the public ceased to believe in NASA or the space program's ability to return to Apollo-era levels of success. Throughout the Cold War, the space shuttle had deployed many covert satellites for the DOD at incredible costs and with varying levels of success. However, as a civilian instrument in the post-Cold War era, Hubble was left open for public criticism and became easy prey upon which politicians and the media could project broad critiques of NASA. The difficulty of communicating the different perspectives of NASA officials, scientists, and politicians to each other is evident throughout congressional transcripts addressing NASA budget allocations and issues relating to the Hubble and the Shuttle.

Astronomers throughout the world waited in line to utilize Hubble for scientific knowledge inaccessible from ground-based telescopes, but the search for astrophysical data was hardly enough justification for most politicians. The primary way in which politicians justified Hubble to taxpayers, and many big science programs, was to emphasize the growth of jobs. The aerospace industry, scientific and academic institutes, technical and manufacturing industries, and government jobs through NASA were expected to be positively impacted by Hubble and

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other large space programs. Research conducted in the early 1970's concluded that for every dollar NASA spends on research and development, seven dollars are returned to the US gross national product.¹⁰⁵ This is a statistic which has been strongly promoted by NASA and although the positive economic impacts of government sponsored aerospace R&D spending have been confirmed by several other studies, ¹⁰⁶ their accuracy remains somewhat arguable in part due to the difficulty in assessing the long term impact of private contracts and the "trickle-down" value of NASA's "spin-off" technologies.¹⁰⁷ It has been a consistent trend, however, that states with NASA centers and headquarters receive significantly more economic stimulus and job growth. These include Goddard Space Flight Center in Maryland, Michoud Assembly Facility in Louisiana, Marshall Space Flight Center in Alabama, Ames Research Center and Jet Propulsion Laboratory among others in California, Kennedy Space Center in Florida, and Johnson Space Center in Texas. These states have in the past received the lion's share of NASA resources and funding, however, in more recent years changes in NASA's programming structure (for instance, SBIR/STTR or the Small Business Innovation Research/Small Business Technology Transfer Program) has facilitated private aerospace expenditures in states such as Colorado which, as of 2012, has the second largest aerospace economy behind California.¹⁰⁸

¹⁰⁵ Midwest Research Institute. "Economic Impact of Stimulated Technological Activity." Kansas City, Missouri: Midwest Research Institute, November 1971.

Chaisson, The Hubble Wars, 30.

¹⁰⁶ Chase Econometric Associates, Inc. "The Economic Impact of NASA R&D Spending: Preliminary Executive Summary." NASA-2741, April 1975.

Rockwell International, Space Division. "Impact of the Space Shuttle Program on the California Economy." FD-74-SH-0334, December 1974.

J. Schnee. "Government Programs and the Growth of High-Technology Industries." Research Policy. Vol. 7, No. 1, January 1978, 2-24.

¹⁰⁷ Hertzfeld, "Measuring the Economic Returns from Successful NASA Life Sciences Technology Transfers," *The Journal of Technology Transfers* 27 (2002): 311-20.

¹⁰⁸ Aerospace States Association, http://aerostates.org, 2014. Accessed 3/12/14. "NASA's innovation Impacts Across the US," NASA,

http://www.nasa.gov/offices/oct/tech_transfer/economic_impacts.html, 2012. Accessed 3/12/14.

Barbara Mikulski, a democratic senator from Maryland since 1987, participated in a 1991 senate hearing on the many problems at NASA, including Hubble, the Space Shuttle, and Space Station Freedom. She described herself as a "space Senator" in which she acknowledged her state's link to the space program through the Goddard Space Flight Center and the Space Telescope Institute at Johns Hopkins, in addition to her longstanding support for the "values and ideals and goals" of the civilian space program. Goddard controls use of the instruments on board Hubble and manages development of its future successor, the James Webb Space Telescope. In the 1990's Goddard employed around 13,000 people, of which more than half were scientists and engineers. Goddard had a budget of approximately \$2 Billion per year in the 1990's, of which "commercial firms received 60%, educational institutions received 28%, nonprofit organizations received 8%, other government agencies received 3%, and 1 % was awarded outside the U.S."¹⁰⁹ Despite her apparent ideological as well as political and economic commitment to the space program, she describes the "serious flaw in Hubble's primary mirror" as a "devastating blow to NASA" which "sums up the history of the spectacular space-based project: cost overruns, NASA and contractor mismanagement, and the frequent absence of quality control."¹¹⁰ Mikulski argued NASA's large "spectacular" projects had become victims of systemic issues.

The congressional discussion of NASA problems is illustrative of discursive differences between individuals at NASA such as scientists who are directly involved in the technical aspects of the space program, and politicians and media entities which are not. In the 1990 congressional hearing on the Hubble flaw, NASA administrator Admiral Richard Truly

¹⁰⁹ "Goddard Space Flight Center Economic Impact FY99," NASA.gov,

<http://www.hq.nasa.gov/office/hqlibrary/documents/GSFC_Econ_Imp_FY99.pdf> Accessed 3/12/14. Julia Angwin, "Goddard Center Faces NASA Cuts," *The Baltimore Sun* 22 February, 1995. ¹¹⁰ U.S. House of Reps, *Hubble Space Telescope Flaw*, 2.

described the spherical aberration as an "error in the curvature of the mirror...which was to be smooth within about 1/50th of one wavelength of light at a particular frequency," he went on to say that "it appears that a likely candidate [for the cause of the flaw] was a simple error made in the manufacture of the primary mirror." The use of the word "simple" was then interrogated by congressman Roe:

I think that some clarification has to be made, if I may. Number one, we use the word "simplicity," and I think you're using it in the technical term, not simplicity in the order of magnitude of the problem we're faced with. I mean, it's not a simple problem by any stretch of the imagination to correct something that's been manufactured incorrectly.

To Roe, the magnitude of the issue was more accurately measured by the expense and the level

of negative public reaction to the flaw. Roe went on to have this one-sided exchange with

Lennard Fiske, NASA's Associate Administrator for Space Science:

Roe: Where I'm coming from, it seems to me that the first and foremost issue in the minds of myself and, I think, most of the members and the people of this country, is this thing a dud? I have to bring it down to that simplicity. Is it a dud? Fisk: It isn't... Roe: Let me finish. The question is not complete. I want to just let that sink in. Is it a dud? That's number one. Did we spend a billion and a half or more dollars and build a telescope that, according to some of the press, doesn't produce what it was supposed to produce? And can never produce what it was supposed to produce, according to some of the articles I have read. Should we have spent this kind of money and all of the problems and frustrations of this Hubble over the period of time, or did we waste the money? ¹¹¹

The NASA administrators went on to describe the flaw as something fixable, and the HST as an

instrument which would still achieve essentially all the scientific goals that it set out to achieve.

For Roe and his colleagues, the Hubble flaw took on a greater magnitude in part because

of their reliance on popular news media to understand the extent of the issue, as well as the

constant reminder of "what we went through four years ago after the Challenger."¹¹² Scheuer,

and other politicians, went on to ask "how could the science fail?" In this instance the Hubble

¹¹¹ U.S. House of Reps, *Hubble Space Telescope Flaw*, 6.

¹¹² U.S. House of Reps, *Hubble Space Telescope Flaw*, 22.

flaw was not perceived as a result of systemic issues at NASA or in Congress, but as a representation of the unthinkable failure of American "Science" to live up to an aggrandized standard of scientific infallibility and idealized cultural memories. For Hubble to represent American Science as a whole, even symbolically, reflects on the profound alienation between the technical-scientific community and everyone else. Rather than be understood for its embeddedness within the military, industrial, and civilian science programs and the enormity of its data gathering capacities, Hubble was briefly nothing more than a myopic reminder of American failure to live up to American expectations of "space spectaculars" past.

Republican Senator Edwin Garn, who flew in space as a Payload Specialist on space shuttle *Discovery*, argued that media outlets and "some politicians" had inaccurately and unfairly taken NASA's technical problems and used them as a way to disparage the entire program while ignoring a long record of successes. In the 1991 congressional hearing Garn stated: "The real test of agency competence is how these issues are addressed and resolved... I see the press out there as a bunch of piranha and some of my colleagues as the same...who seem to enjoy kicking someone when they are down..."¹¹³ Garn's unique position as both a politician and an astronaut undoubtedly influenced his emphatic defense of NASA to congress:

I am sorry to take so much time, but it disturbs me. As one who has been inside NASA. It still has the most technically competent, capable people of any Government agency, and the most dedicated astronauts, the cream of the crop of America's scientists, pilots, and administrators. There is not another agency that compares. But we are going to kick them when they are down and we are going to take isolated events and bring them together...Yet the press has to say, oh, we've got Hubble, we've got the shuttle, and we've got these astronauts and all these problems, like they are just groping and looking, finding every little tidbit to make the agency look bad. Well, this Senator resents that. I would like to take some of those people with me. I would like to have them spend some time down there and see how these people work, all throughout NASA, the cast of thousands that makes a mission possible, not just for the astronauts. Then I would like to

¹¹³ U.S. House of Reps, *Hubble Space Telescope Flaw*, 2.

take some of the gutless wonders out there on a space shuttle trip, if they had the nerve to go. I would probably need some big diapers, however, to take care of their problems.¹¹⁴

The passionate, and probably offensive to some, way in which Senator Garn argued his point reflects on the powerful and deeply personal way in which the culture of the space program can impact the fundamental value systems of those integrated into it. Astronaut Gus Grissom is quoted in the years before his 1967 death in the *Apollo 1* fire: "If we die, we want people to accept it. We're in a risky business, and we hope that if anything happens to us it will not delay the program. The conquest of space is worth the risk of life."¹¹⁵ That sentiment is echoed by many astronauts, scientists, and space enthusiasts, including NASA administrator, Admiral Richard Truly while addressing congress in 1991: "When you run complex programs that are run by human beings, failures and anomalies are going to happen. Space flight is a risky business.

The role of "space spectaculars" was important in the arguments of both Senators Mikulski and Garn. While productive scientific data may be produced at NASA and other institutions on a daily basis, those discoveries are limited to the few, the scientists, who have the comprehension to appreciate those discoveries and the communities to interpret them. Space spectaculars are determined by their accessibility to the public and to non-scientists in general. When things such as the moon landing or the launch of Sputnik occurred, whether good or bad, they overwhelmed the rest of the space program. Senator Garn addressed this phenomena:

When you consider such a relatively brief period of time, from the late 1950's, not having the ability to fly anything in space –and we experience this with the *Challenger* accident. Nobody talked about the fact that 52 manned missions were successfully completed in space without one fatal accident. They concentrated on the *Challenger* accident.¹¹⁷

¹¹⁴ U.S. Senate, Problems at NASA, 4.

 ¹¹⁵ Virgil "Gus", Grissom. Cited in, "NASA History, Detailed Biographies of Apollo I Crew," (NASA.gov, 2006)
Retrieved from: http://www.hq.nasa.gov/office/pao/History/Apollo204/zorn/grissom.htm. (Accessed, Jan. 2014).
¹¹⁶ U.S. Senate, *Problems at NASA*, 11.

¹¹⁷ U.S. House of Reps, *Hubble Space Telescope Flaw*, 3.

The early Cold War emphasis on prestige set the precedent for space spectaculars to play a key role in the national space program. The enduring popular legacy of the moon landing was not that everyone learned all about what moon rocks were made of, but that an American man planted an American flag on another celestial body and everyone got to watch it on TV. The Apollo program was one of the first examples of big science in the United States, although the vastness of the program is often reduced in popular culture to Neil Armstrong's single misquoted line. The Cold War propaganda as it was aligned with the Apollo program helped to establish NASA's position in American popular culture and all of the heightened expectations that went along with that. NASA's popular and cultural significance would likely have been drastically altered had the Apollo program been less successful.

Although the mid-century propagation of the heroic astronaut image was positive in the sense that it increased awareness and popularity of the space program, it also set the standards for success very high and mythologized the science behind NASA programs. The popular expectations of visually exciting and emotionally impactful space spectaculars limited the ability of otherwise scientifically important programs to gain the recognition and support they may have needed to succeed. Although media outlets, politicians, and different groups often critique the big science programs when they go wrong, they somewhat paradoxically expect the space program to mimic the past and recapture their imagination through spectacular programs which can only really be accomplished on a massive scale, over many years, and with the involvement of thousands of individuals, agencies, and entities.

In the early 1960's big science was already subject to criticisms. Allen Weinberg questioned whether science would be ruined by the injection of too much money into

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bureaucracies which would then make big science "fat and lazy."¹¹⁸ These fears remained very relevant in the 1990's and the issue remained somewhat polarizing for scientists and non-scientists alike. "The Federal Government has embarked on the most ambitious array of big science projects ever, with some experts saying they herald a new age of discovery while others are warning that their great cost could cripple vital parts of the nation's scientific effort and eventually the American economy."¹¹⁹ A 1990 article in the New York Times enumerated many criticisms of big science:

"Big science has gone berserk," said Dr. Rustum Roy, professor of materials science at Pennsylvania State University, who is an adviser to the House Committee on Science. "Good minds and a lot of money are going into areas that are not relevant to American competitiveness, American technological health, or even the balanced development of American science." ..."We have a crisis developing," said Representative George E. Brown Jr., a California Democrat who has served on the House science committee for nearly a quarter century. "We're freezing out a lot of our good work because of the commitment to big science." In dealing with inevitable costs rises, [Frederick N. Khedouri, a budget official in the Reagan White House who oversaw most of the nation's big-science projects] said, managers at Federal agencies often "sacrifice less visible but probably more important programs." The overall effect, he said, "is a system in which bad science tends to drive out the good." ¹²⁰

Big science was perceived in some ways to be at odds with the "nature" of science and at odds with "good" science. Although the many critiques of big science were valid in many ways, they were also imbued with the idea that "the science" should always perform according to certain beneficent expectations.

The way in which people perceive the relative morality of science is rooted in sociopolitical historical contexts which constructed an idea of scientific purity, scientific might, and determined a particular trajectory for large scientific endeavors. Many critiques of big science fail to mention the impact that the military and the quest for American dominance in space has

¹¹⁸ Weinberg, "Impact of Large-Scale Science on the United States," 161

¹¹⁹ William Broad, "Big Science: Is it Worth the Price?" *The New York Times* 27 May 1990 ¹²⁰ Ibid.

had on large scientific endeavors in the United States and elsewhere. The role of politics and the military in shaping science can often be blatantly ignored or unseen by media outlets and others because of the flawed socio-cultural construction of "Science" as something that should unquestionably be a positive force. The same 1990 newspaper article which enumerated the flaws throughout big civil science argued that:

Experts have no formal definition of "big science," but for the purposes of this article it is seen as any civilian research project whose construction costs are \$100 million or more. This definition excludes military endeavors like the Strategic Defense Initiative, or Star Wars, on which more than \$20 billion has been spent so far, and high-technology development programs like the proposed \$5 billion aerospace plane that would fly off a runway into earth orbit. Such programs can have much the same impact in siphoning off money and technical talent from other worthy projects, but they are not usually considered scientific in nature.¹²¹

It would seem blaringly contradictory that simply because programs operate under military auspices and without civil oversight that they would not be considered "scientific in nature." Although the Strategic Defense Initiative in particular was not based on verifiable or realistic science, the extensive nature of the military's scientific endeavors and the military's role in enabling big science is virtually unarguable. The inaccessibility of military science because of its often classified status can have negative impacts on the civil agency, NASA, which is forced to represent the whole of science programs which are only fractionally determined by civilian directives. While the loss of *Challenger* was a blow to the budget and efficiency of the Defense Department, it was NASA's reputation and the reputation of the civilian space program which was irreparably damaged. Similarly in the case of Hubble's flaw, politicians and the media found little prerogative to look beyond NASA for the causes of the error.

An article published by science writer Dennis Overbye three years later on the eve of STS-61, Hubble's first repair mission, described Hubble as an idea "cooked up" by Lyman

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¹²¹ William Broad, "Big Science: Is it Worth the Price?" The New York Times 27 May 1990

Spitzer, subject to the "spinmasters" at NASA, and "a relic of a time when NASA thought humans could do anything and everything in space."¹²² The article goes on to speak for NASA as if it was, again, the only entity responsible for space science and the only entity responsible for the trajectory of the United States space program:

The space agency itself likes to view the Hubble repair as evidence of a new NASA -- or of the good old NASA returned. But optimistic rhetoric cannot disguise the fact that NASA has foundered for a mission ever since it beat the Russians to the moon. With the Cold War over, the public appetite for ambitious scientific projects has diminished. And NASA offers no new dream to lift us, or itself. The proposed international space station and Mission to Planet Earth may be responsible public works projects, but they are hardly stirring. To save the world -- or at least regain its own technological edge -- NASA needs an inspiration, and the universe is waiting.

Overbye inferred, whether intentionally or not, that NASA has been impacted by the military. A civilian agency, after all, would not have been concerned with "beating" anyone to anywhere. He claimed it was the end of the Cold War which satiated the "public's" appetite for ambitious scientific projects, a statement which also ignored the role of the military in determining "public" projects. It would also seem plausible that the public's passion for the space program was slowly diminished well before the fall of the Soviet Union because of the military's heavy hand in determining the course of the program. Perhaps it was and is true that NASA is often left "floundering" for a mission in the absence of overt military need and it is by definition, easier to identify the flaws of a civilian program than the flaws of a covert militant program. However, the very critiques that Overbye leveled against NASA speak to the underlying role that NASA has always played in the American cultural imagination despite its military duality. Overbye argued that somehow NASA is capable of "saving the world" if only it offered a "new dream to lift us." The idea that NASA, despite all of its flaws, could somehow still be capable of uplifting an entire society illustrates the profound power and impact that the successful space science

¹²² Dennis Overbye, "Hubble Jeopardy," The New York Times 28 Nov 1993.

programs have had on American culture and the American psyche. The hope and inspiration that NASA has come to represent for many people make it equally catastrophic to the sense of American exceptionalism when NASA or "American science" is perceived to have failed.¹²³

The Hubble mirror flaw was especially emphatic because it was visible to the public through tangible (and blurry) images of space. The flaw was a material manifestation of the perceived inadequacies and inefficiencies of private contractors, astronomers, NASA, and public officials. Senator Garn argued, however, that if

Hubble were sending back beautiful pictures nobody would be questioning NASA management...You can shake up NASA management every day of the week. You can turn it upside down... You can change Congress. And that would not have prevented the technical tragedy that has taken place because of the lack of some proper tests 10 years ago.¹²⁴

Fortunately for the reputation of NASA and all involved in the Hubble program, Garn's statement regarding the popularization of Hubble photographs certainly rang true in the long term. His argument raised the question of the logic and necessity of assigning blame for an event such as the Hubble flaw. Perkin-Elmer was the contractor in charge of polishing the primary mirror in the 1980's as Garn pointed out, however the development and construction of a program as complex as the HST involved the interaction of an almost innumerable number of factors over several decades, making the identification of the one "true" reason behind the flaw a daunting if not somewhat unrealistic task.

¹²³ Dennis Overbye, "Hubble Jeopardy," The New York Times 28 Nov 1993.

¹²⁴ U.S. House of Reps, *Hubble Space Telescope Flaw*, 4.

Chapter 5: Disillusionment and the Move Towards Commercialization

The American space program was initially built upon the ideological conflict and military buildup between the United States and Russia. In the context of the Cold War, technological failures in space and on the ground could be validated in part by the necessity to further American exceptionalism in the world no matter what the cost. After several years of recession and "stagflation" in the 1970's during the Nixon and Carter presidencies, President Reagan campaigned on a platform of reduced government spending, de-regulation, and supply-side economics which ultimately shifted the space program budget in favor of military appropriation.¹²⁵ This shift perpetuated the dominance of wartime prestige-driven science spending over other scientific or academically based civil space programs.

Although it could be argued that NASA lost course soon after the success of the moon landing, the space program was under increased pressure to prove its value in the early 1990's after the end of the Cold War and in the wake of *Challenger*. Manned space flight had been emphasized throughout the space program because it "served a valuable prestige purpose during the space race" and could more easily garner political support, however the de-emphasis on technological dominance and status in space after the end of the Cold War in 1991 meant scientifically driven programs would have to come to the forefront of the space program in favor of space spectaculars.¹²⁶ The end of the Cold War marked the end of legitimate justification for a space program based heavily on missions with mass appeal or covert military imperatives, like the space shuttle. Chief historian at NASA, Roger Launius argued that the "prestige trap" of the space race era resulted in misguided directives within the space program from very early on:

¹²⁵ See Image 6 on page 39 depicting the space program budget between 1970 and 1990.

¹²⁶ Roger Launius, "Imprisoned in a Tesseract: NASA's Human Spaceflight Effort and the Prestige Trap," *Astropolitics: The International Journal of Space Politics and Policy* (2012) 10:2, 152-175.

No one intended to be boxed into a particular approach to space activities, but over time NASA's policy options have been narrowed by its long history with this aspect of the space enterprise. Despite changing national priorities, evolving international situations, emerging political positions, and advancing technologies in robotics and electronics that might otherwise prompt major shifts in policy and mission, NASA has clung to the human spaceflight model advanced at the height of the Cold War when prestige vis-a`-vis the Soviet Union prompted emphasis on this human dimension. As the Cold War ended, however, this rationale has lessened in its hold over the nation and NASA has been cast adrift in its justifications for human spaceflight.¹²⁷

The end of the space shuttle program and the gradual move away from Hubble towards its potential successors represents in some ways the end of an era for the national space program. Hubble's development throughout the 1970's and 1980's was often sidelined by the shuttle and by other military satellite programs. Upon its launch in the 1990's, however, in the brief absence of war and the weakened state of the manned space program, the entire civilian space program and NASA had a heightened stake in Hubble's success. The compounding economic, political, and cultural effects of the space shuttle events, Hubble's flaw, and other issues in the program highlight the ability of technology to "shape a variety of social processes, sometimes according to human plans, but just as often *not*, or at least not quite."¹²⁸ The large networks of scientists, administrators, and agencies which facilitated scientific development in the space program were also contingent on the technology itself. The impact of Hubble's initial flaw combined with the disasters of the shuttle program were enough to call into question the government's ability to adequately, efficiently, and safely conduct big science in space.

The issues which have taken place in the last 30 years of the space program have also played a significant role in diminishing the American pride in the space program which

¹²⁷ Ibid.

¹²⁸ Timothy Mitchell, "Can the Mosquito Speak?" in *Rule of Experts: Egypt, Techno-Politics, Modernity* (Berkeley: University of California Press, 2002) 30.

characterized the Apollo era. Addressing the end of the shuttle program in 2011, a New York

Times article lamented:

As the centerpiece of our country's gaudily ambitious space adventures, the shuttle program was a pre-eminent symbol of our belief that there were literally no limits to where we could go and no boundaries to what we could accomplish, so long as we hitched our ingenuity to our imagination and marshaled the requisite will. And there's no real sense of what big dreams, if any, lie beyond *Atlantis*. The program's end carries the force of cruel metaphor, coming at a time when limits are all we talk about. When we have no stars in our eyes...

Americans right now are profoundly doubtful. Shaken. For many, the fear isn't just that there's no imminent end to high unemployment and tepid economic growth, but that we've turned a fundamental corner and our best days really are behind us...Despite the president's exhortation that we chart the frontiers of innovation, there's no grand mission that represents the kind of storehouse for our confidence and emblem of our can-do spirit that space exploration once did.¹²⁹

Despite the programs tragedies and inefficiencies, it would seem that Americans still wanted to believe in not only the shuttle program, but in the possibility of American human space flight and space science in general. The early success of Apollo and the cultural imprint of the moon landing provided, in the long run, more consistent support for the American space program than any political or economic reasoning could. However, the nostalgia of the midcentury space program can only subsist for so long. Although the national space program as it is represented by NASA does and will likely always play an important role in providing direction and leadership to American ventures into space, the space program finds itself in a somewhat transitional period in response to weakened socio-political funding and support as well as indistinct mission directives.

James Sensenbrenner, a conservative congressman, argued in the early 1990's that the Hubble flaw suggested "serious deficiencies in NASA's ability to estimate costs and to monitor contracts and an organizational attitude which places too low a priority on risk management,

¹²⁹ Frank Bruni, "In an Earthbound Era, Heaven Has to Wait," *The New York Times* July 6 2011.

testing, and verification. Perhaps these are all symptoms of NASA's unwavering confidence and optimism to meet every challenge despite limited resources.³¹³⁰ Sensenbrenner's statement raises the question of what cultural role NASA would have filled if it did not attempt to meet challenges with confidence and optimism. Idealized and unrealistic as they may be in practice, NASA programs have long been defined from a cultural standpoint by President Kennedy's famous 1962 statement that the United States should engage in space science programs "not because they are easy, but because they are hard." The often quoted line has come not only to represent NASA but to represent American cultural ideals of leadership, ingenuity, and exceptionalism. President Reagan attempted to evoke the same ideals to a captive, if significantly less enthusiastic, audience in 1986 when he contended that "it's all part of taking a chance and expanding man's horizons. The future doesn't belong to the fainthearted; it belongs to the brave."¹³¹

The different views of politicians who had addressed the Hubble problem seemed to be influenced in part by the significance they placed on the Apollo program, their evaluation of its role in American history, and the level to which they feel it is necessary to continue supporting risky, technologically complex endeavors in space science. James Scheuer, a democratic congressman, described the Hubble flaw as "involving the hopes and expectations and the excitement of the entire American public."¹³² It seems unlikely that discussions of the Hubble flaw would have been so polarized if they had not taken place in the context of the 1986 *Challenger* tragedy and against the backdrop of the end of the Cold War. The different ways in which politicians, officials, and the media interpreted and allocated blame for the Hubble flaw

¹³⁰ U.S. House of Reps, *Hubble Space Telescope Flaw*, 6-7.

¹³¹ Peggy Noonan, "Address to the Nation on the Explosion of the Space Shuttle Challenger." Reagan speech transcript, 1986.

¹³² U.S. House of Reps, *Hubble Space Telescope Flaw*, 21.

was used as a way in which they could express their own valuations of the space program in general.

Although Hubble's development was ingrained in the space race much like the space shuttle, Hubble also represented a necessary turn in NASA's directives in which scientific missions needed to be prioritized over riskier endeavors which could potentially be left to commercial aerospace enterprise. NASA faced an uphill battle in proving the socio-political value of scientific unmanned missions and Hubble represented the perfect opportunity to do just that. The Hubble flaw and the idea of a multi-billion dollar "piece of junk uselessly orbiting the earth", however, threatened to complete the disillusionment of an already traumatized public.¹³³

The political and public turmoil which existed because of the flawed HST in the early 1990's exhibited the extent of the detachment between the scientific community and everyone else. NASA, astronomers, and scientists who worked on the Hubble were part of a limited community of individuals who had an understanding of Hubble's technology and of the data at stake. John Naugle, a former chief scientist at NASA, emphasized the need to eliminate barriers between seemingly elite scientific groups and the public:

Scientists must recognize that where they are dependent upon public support for their endeavors, they must communicate the importance of their endeavors to the public – the knowledge they have gained and its significance. This enables the public to participate, in many cases vicariously, in these activities. If scientists devote perhaps one-tenth of the creative energy devoted to understanding the universe to explaining to the public the reasons for and importance of what they are doing, then I think the problems that we have in obtaining support for basic research will disappear.¹³⁴

In this case, Naugle argued in favor of the idea that there is a "knowledge deficit" existing primarily due to a flawed and under-prioritized educational system in the United States. Conflicts

¹³³ Chaisson, The Hubble Wars, 187.

¹³⁴ John Naugle, "Epilogue," in *Large Space Telescope – A New Tool for Science* (Washington, D.C.: AIAA, 1974), 124.

between scientists, politicians, and the media, result in part from an imbalance in knowledge about the fundamental nature of the research being conducted. Some researchers have argued, however, that the mere spread of scientific knowledge is not enough to bolster support for scientific and technological endeavors.

Political scientist Samuel Popkin and others have argued that public opinions on science and technology are often formed primarily by media biases and political framing more than any other factors. The concept of "low-information rationality" is based on "the assumption that human beings are cognitive misers and minimize the economic costs of making decisions and forming attitudes. Most citizens will therefore not bother to develop an in-depth understanding of scientific issues…"¹³⁵ Dietram Scheufele of the Department of Life Sciences Communication at the University of Wisconsin argued that:

Many of the academic debates about how citizens form attitudes about scientific issues come down to a conflict between ideals and realities. On one side, many of the recent public outreach efforts are based on somewhat idealistic views about a 'scientific citizen' who forms attitudes based on an in-depth understanding of scientific controversies, or should do. On the other, we have decades of research in social psychology, political science, and risk communication that suggests that knowledge plays a marginal role at best in shaping people's opinions and attitudes about science and technology. In fact, many researchers have suggested that the way media present an issue, and people's value systems and predispositions, play a much greater role in shaping citizens' attitudes towards new technologies.¹³⁶

This idea critiques the "knowledge-deficit" model held by many advocates of popularizing science and suggests that scientists and other advocates should attempt to be more aware of the "cognitive shortcuts or heuristics" that people use to navigate the massive influx of information they consume on a daily basis.¹³⁷ In this way it is necessary to acknowledge the role of political

¹³⁵ Dietram Scheufele, "Messages and Heuristics: How Audiences Form Attitudes about Emerging Technologies."

In Engaging Science: Thoughts, Deeds, Analysis, and Action. Ed. by Jon Turney, (Wellcome Trust: 2007), 21.

¹³⁶ Scheufele, "Messages and Heuristics", 20.

¹³⁷ Ibid.

framing in translating science to non-scientists. In this way, the political forces involved in NASA funding, program approval, and official appointments are of special importance to the perception and existence of the space program. Scheufele and Popkin's argument of a "miserly" citizen may be considered a pessimistic take on human nature. However, it would also seem unrealistic to assume that the public can become adequately informed about huge network programs such as Hubble in an unbiased way in the absence of a widespread increase in government and corporate transparency in addition to a widespread improvement in access to scientific education. Both of these changes, while technically possible, are highly unlikely to occur in a useful timeframe to benefit the immediate scientific community or the public. Therefore, scientists and technological advocates must likely rely on a variety of different avenues to successfully promote the message and agenda of science to the public.

Whether or not the public is receptive to the knowledge does not negate the fact that the scientific and social value of many technologically complex programs is often inadequately or insufficiently communicated to non-scientists, which strips away the real meaning of programs such as Hubble. A broadening spectrum of individuals have attempted to amend this prolific issue through mainstream or "popular science." Making science palatable for the uninitiated is a complex task which few individuals have truly excelled at. In the field of space science, individuals such as Isaac Asimov, Carl Sagan, and Neil deGrasse Tyson have been notably successful in their attempts to interpret science, although not without difficulties. Not only is it difficult to interpret the scientific and technical complexities of scientific principles to the uninformed or uninterested, it is also difficult to align or make compatible the scientific message with other worldviews, spiritual and otherwise.

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Like any relatively small group of people with a specific and unique set of goals, scientists run the risk of becoming alienated or detached from the mainstream. This separation comes in part from the depth of commitment held by scientists to the discovery of scientific truths and to the values of the scientific community. Even pro-space politicians often hold a very different perspective on space science than do the actual scientists involved. When asked to justify the millions of dollars spent on the Hubble repair mission, Astrophysicist Eric Chaisson focused on the ideals of "exploration," "curiosity," and "education," whereas in response to the same question Senator Barbara Mikulski simply focused on "jobs."¹³⁸ The modern political climate is not as accepting of science for the sake of science as it was in the past for science in the name of American exceptionalism.

Despite Hubble's use as a civil scientific instrument in the early post-Cold War, it remained fundamentally embedded in the culture of a space program which had not yet evolved beyond its military beginnings or beyond the expectations lingering from the Apollo era. The Hubble program, like the space shuttle, was only as good as the sum of its parts. The foundations of the space program degraded throughout the latter half of the 20th century, not because of a lack of scientific need or ingenuity, but because of the increasingly questionable need for a military presence in space and an increasingly disenchanted public.

Programs such as Hubble would be impossible if not for the vastness of the resources committed to its organization, research, and development, however that level of complexity also distances the finished product from the networks which created it and from the public who ultimately stand in judgment. The enormity and complexity of the program, and many other large scientific programs, rendered it difficult if not impossible to be meaningfully represented to the

¹³⁸ Chaisson, The Hubble Wars, 368.

broader public. The Hubble Space Telescope is only one contemporary case of a big science program which was distilled into a single event and nearly defined by a single flaw.

Although it may be fair to say that most astronomers now largely hail Hubble and its subsequent repair as one of the most successful and important scientific endeavors of all time, not everyone in the scientific community felt so optimistically about the legacy of Hubble. Astrophysicist Eric Chaisson lamented that the 1993 Hubble repair was merely another way in which manned space spectaculars could steal the spotlight, and the support, for more scientifically productive programs.

Much as the space shuttle program had cannibalized NASA's science projects in the 1970's and 1980's, government-sponsored space science would now once again take a back seat to crewed space flight, engineering demonstrations, and space spectaculars that excite the public to demand more space spectaculars. Even before we knew if any of the instruments installed by the STS-61 crew worked properly, the rallying cry within NASA had become, "Onward to the space station"—which to many of us scientists resembles an attempt to orbit a largely empty, hundred-billion-dollar garage in the sky.¹³⁹

Chaisson's critique, while arguably justified, reflects on the "imperfect marriage" that was Hubble and the space shuttle. Hubble and other scientific civil programs may have been better off without the shuttle, and many would likely testify to that, however the five shuttle servicing missions to prolong the lifespan and productivity of Hubble proved both necessary and successful. Chaisson's critique was written before *Columbia* occurred, which may account in part for his conviction that that space shuttle type programs would ultimately prevail over programs like Hubble. In some ways the opposite has occurred however, and Hubble is often considered the final redemptive note of the shuttle program which came to a relatively quiet end in 2011.

¹³⁹ Chaisson, *The Hubble Wars*, 362.

The knowledge derived from Hubble observations has been transformative for astrophysics, astronomy, and Hubble's postprocessed images have provided non-scientists with the first glimpses into deep space. An article in the New York Times painted a romanticized picture of the so called "Pillars of Creation" in the Eagle Nebula as it was first photographed by Hubble in 1995. The article describes a "fantasyland of powerful cosmic forces…bathed in a flood of ultraviolet light from nearby young, hot stars, billowing columns of cold gas and dust rising ominously out of a dark molecular cloud like stalagmites from the floor of a cavern."¹⁴⁰ Although the impact of Hubble's photography on the



Image 10: Eagle Nebula Detail. Source: NASA, ESA.

popular perception of space science has been immense and provided an important reprieve for

NASA's reputation, the science behind these images has also been incredibly productive.

Engineer and historian Thomas Heppenheimer described Hubble's early data:

This was science at its best, raising deep issues at the foundations of astrophysics. It was not a simple matter of routine experiments and modestly improved findings. Rather, the Hubble Telescope was calling into question the basic methods of astronomy, casting doubt on what scientists truly know and how they claim to know it. Yet this telescope would stand at the forefront of work aimed at resolving this paradox, by sharpening the estimated age of the cosmos.¹⁴¹

One of Hubble's most significant contributions has been the Deep Field and Ultra Deep Field images which located 13.2 billion year old galaxies, the oldest ever seen in the 13.7 billion year old visible universe. The Deep Field images were not simple snapshots, however, and required

¹⁴⁰ John Noble Wilford, "A Stunning View Inside an Incubator for Stars," *The New York Times* 3 Nov, 1995.

¹⁴¹ T.A. Heppenheimer, *Countdown: A History of Space Flight*, (New York: John Wiley and Sons, 1997), 350.

the combination of a decade's worth of photographs each exposed over the course of days.¹⁴² The analysis of galaxy movement overtime demonstrated that the universe was expanding at faster rates, rather than being slowed by a central gravitational pull as formerly surmised. The Hubble Space Telescope has provided data that confirmed paradigm changing theories of universe expansion, provided evidence for the presence of dark energy, in addition to the discovery of numerous planets and stars in the 23 years it has been functioning.



Image 11: Hubble Extreme Deep Field Detail, 2012. Source: NASA, ESA, Illingworth, Magee, Oesch, Bouwens, HUD09.

Many of these discoveries would not have been possible without the installation of many improved scientific instruments developed for use on Hubble. All of the instruments currently operating on Hubble were built by Ball Aerospace with oversight by Goddard and the Space Telescope Institute, including the Wide Field Camera 3 and the Advanced Camera for Surveys which made the later Deep Field images possible.¹⁴³ The national space program in the post-Cold

¹⁴² "Hubble Goes to the Extreme to Assemble Farthest-Ever View of the Universe," NASA, 2012. Retrieved from: http://www.nasa.gov/mission_pages/hubble/science/xdf.html (Accessed 3/20/14).

¹⁴³ "Hubble Space Telescope," Ball Aerospace and Technologies Corp, 2014. Retrieved from: http://www.ballaerospace.com/page.jsp?page=69 (Accessed 3/20/14).

War era attempted to shift the culture and directives of NASA towards "smaller, cheaper, faster, better" missions under the auspices of then NASA administrator Daniel Goldin who succeeded Richard Truly in 1992.¹⁴⁴ Goldin successfully oversaw several successful Hubble improvement missions, however his tenure was marred by the failure of several planetary probes.

President Reagan moved towards increasing the marketable potential of space activities with the Commercial Space Launch Act of 1984 which recommended the increased use of private expendable launch vehicles in lieu of manned shuttle flights. Until the *Challenger* disaster in 1986, however, the government subsidization of the shuttle had made it a more attractive option than the Titan, Delta, or Atlas-Centaur rocket families which were built by Martin Marietta, McDonnell Douglas, and General Dynamics respectively.¹⁴⁵ The rapid growth of the global communication satellite industry increased the demand and competition for efficient and reliable launching platforms and helped bolster Reagan's free market agendas.

American political leaders in the 1980's embraced a free market ideology that placed a priority on limiting the size of the federal government. Right-wing ideologues questioned the government's role (aside from the essential functions of defense) in American life. It was no longer obvious to them, or to their allies in Congress, that the federal government should provide lavish funding for basic research in science and technology. In an era of globalization, policymakers encouraged the development of scientific fields that could compete in the global marketplace as well as in the marketplace of ideas. These twin concerns—national defense and privatization—shaped the course of American policy for science and technology in the waning days of the Cold War.¹⁴⁶

The neoliberal political shift favoring deregulation and decreased government spending on science influenced the enactment of policies and programs which directly impacted NASA. For instance, The Commercial Space Act of 1998 "declares that free and competitive markets create the most efficient conditions for promoting economic development, and should therefore govern

¹⁴⁴ Heppenheimer, Countdown, 346.

¹⁴⁵ Heppenheimer, *Countdown*, 339.

¹⁴⁶ Audra J. Wolfe, *Competing with the Soviets: Science, Technology, and the State in Cold War America* (Baltimore: Johns Hopkins University Press, 2013), 121.

the economic development of Earth orbital space."¹⁴⁷ The law argued that more widespread use of commercial resources would significantly reduce costs for the space program. Although NASA has formed contracts with a variety of smaller private firms, those contracts are often inconsistent and brief—unlike longstanding relationships with massive multi-national defense firms such as Lockheed and Boeing, which were both founded in the 1910's and have been relatively constant actors in the aerospace industry ever since.

Efforts to subsidize the private aerospace industry by NASA and congress have largely benefitted the same huge firms which were the most powerful economic and technological actors throughout space shuttle development and the early space program. The Evolved Expendable Launch Vehicle Program (EELV) began in the early 1990's and was intended to facilitate cheap and consistent satellite launch capabilities to replace older platforms. NASA's EELV contract was initially a competition between Lockheed Martin and Boeing, however the two companies merged into the United Launch Alliance in 2005 which allowed them both to obtain the multibilion dollar contract. Lockheed Martin and Boeing have consistently been the top two contractors to NASA and are the largest defense contractors in the world, therefor the formation of the United Launch Alliance has been widely criticized as unfair market monopolization. United Launch Alliance has, however, received additional NASA contracts for heavy lift launch vehicles. Many smaller aerospace firms with competitive technologies, notably SpaceX and Orbital Sciences, have levied antitrust lawsuits against United Launch Alliance with no clear success.¹⁴⁸ Some members of congress have also raised issues with the military and NASA's

¹⁴⁷ "Commercial Space Act of 1998," 105th United States Congress Public Law 105-303. (U.S. Government Printing Office, 1998).

¹⁴⁸ Dan Leone, "Orbital Drops Antitrust Lawsuit Against ULA," *Space News* 20 March 2014. Retrieved from: http://www.spacenews.com/article/launch-report/39926orbital-drops-antitrust-lawsuit-against-ula (accessed 3/20/14).
recent contractual decisions, questioning whether cheaper alternatives at smaller aerospace firms were being fairly considered.¹⁴⁹ The political and military entrenchment of the space program has tied it almost inextricably to a few very powerful corporate entities which severely constrains the movement towards an idealized "free-market" for aerospace science.

At the end of the Cold War heightened levels of economic competition and prioritization of debt reduction moved to outweigh military goals which had provided much of the backbone for federal science funding. As a result of these economic and political trends as well as "public disaffection with big science," it became "more and more difficult for scientists to win grant support from government agencies, and those who were grant-funded faced greater oversight."¹⁵⁰ Although corporations and private companies often provide different forms of grants and sponsorship to academic science and engineering, Wolfe argued that

The new neoliberal consensus had succeeded in shifting American colleges and universities to private, rather than public support...academic scientists increasingly felt the pressure to focus their research on areas ripe for outside investment. Science, which had for so long had ridden the coattails of post-(WWII) American power, suddenly had to pay its own way."¹⁵¹

The need for science to "pay its own way" in a free market system presents a number of

challenges for academic scientists, civil NASA programs, as well as smaller private aerospace

companies.

Keith Cowing, "SpaceX Sues LockMart and Boeing over EELV Venture," NASA Watch, retrieved from: http://nasawatch.com/archives/2005/10/spacex-sues-lockmart-and-boeing-over-eelv-venture.html (accessed 3/20/14).

¹⁴⁹ Ferris Valyn (15 September 2011). "Monster Rocket Will Eat America's Space Program". Space Frontier Foundation. Retrieved 16 September 2011.

[&]quot;The Senate Launch System". Competitive Space. 4 October 2011. Retrieved 20 October 2011.

¹⁵⁰ Dorothy Nelkin, "The Science Wars: Responses to a Marriage Failed," *Social Text* 46/47, 1996. 96-97. ¹⁵¹ Wolfe, *Competing with the Soviets*, 134.

John Kirton, professor of political science and international affairs at the University of

Toronto, elaborates on some of the many vulnerabilities of the aerospace industry in the

economic and political climate of the post-Cold War era:

Entrepreneurs in the space sector face the full range of normal commercial risks... however, they also face extraordinary risks peculiar to their field. These come from the promise of high reward from a truly infinite frontier, the challenge of the enormous investment in capital, technology, and management, the suspense inherent in the high possibility of failure, and the drama of operating under the intense scrutiny of television cameras and of millions of viewers and the politicians who represent them...It is extremely dependent scientifically and technologically. It needs a constant stream of innovation and invention and perpetually faces the possibility that at least some breakthroughs will not come in time or in the expected direction.

Moreover, space is often an exercise in 'big project science,' requiring many highly diverse inputs to come together in products that are few in number, often distinctive and experimental in character, and seldom characterized by strong economies of scale. Furthermore, space presents formidable managerial challenges, requiring the integration of diverse disciplines, the highest standards of product and process technology, and the sustenance of such performance over extended periods of time...Pushed by the genie of technology on the one hand and pulled by the often perverse logic of politics on the other, the world's space industry waits for a time when significant parts of it can operate as normal businesses do. The latter years of the 1980's were to have been that time, but at the end of the decade the space industry may well be much like the government-dominated entity that now exists.¹⁵²

Kirton's analysis of the stresses of the aerospace industry demonstrates in part the heightened

difficulties present in a network of research and development made up of many different complex and disparate entities. Even if the economic capital, managerial organization, and sociopolitical support are present in a given endeavor, nothing can be successful without the presence and cooperation of scientific and technological objects and network entities. Scientists and engineers are dependent on the discovery and growth of new technologies and in many circumstances no amount of money or political framing can completely alter the impact of scientific discoveries and technological events. John Law argued that "the technologist has to be

¹⁵² John Kirton, "An Uncertain Take-Off: The North American Space Industry in the 1980's," *International Journal* 138, 1986. 140-141.

seen as attempting to build a world where bits and pieces, social, natural, physical, or economic, are interrelated and *keep each other in place* in a hostile and dissociating world."¹⁵³ Big science networks like that which formed Hubble struggle to mediate and translate scientific objects with the realities of socio-economic, political, and cultural forces. Law argues that "the social and the natural are subject to continuous reworking" and therefore should not be used as the primary explanation for other "events or processes." In this way he argues that technological change is "best seen as a function of heterogeneous engineering in which systems containing both the social and the technological are constructed in a context of conflict with other actors, both natural and social."¹⁵⁴ The successes and failures of the shuttle program and the Hubble Space Telescope are examples of the power of technological objects to directly impact the people, agencies, and other technological objects within and external to their vast networks of development.

The lack of federal stimulus for civil space science has put ever more pressure on large scientific programs like Hubble to prove their worth to entities which would provide funding. As the United States moves farther away from the prestige-driven space program of the past that conflated military and scientifically driven projects, large-scale civil science projects like Hubble become increasingly less likely to receive adequate funding or support in the absence of broader cultural prioritization of science and technology. Historian Audra Wolfe asks

What will become of those areas of science, like astronomy or high-energy physics that lack reasonable prospects for market exploitation...? Since the wars in Iraq and Afghanistan, some university researchers have once again turned to the defense establishment, but, as with SDI, the greatest portion of recent military R&D funds have flowed directly into the coffers of defense contractors rather than into university infrastructure.¹⁵⁵

¹⁵³ John Law, "On the Social Explanation of Technical Change: The Case of the Portuguese Maritime Expansion," *Technology and Culture*, Vol. 28, No. 2 (Apr., 1987), 230-231.

¹⁵⁴ Ibid.

¹⁵⁵ Wolfe, *Competing with the Soviets*, 150.

The future of big federally funded science programs like Hubble remain ambiguous and politically unstable. Hubble's successor, the James Webb Space Telescope, is one of the NASA's last remaining big science programs. Scientifically ambitious, the James Webb Space Telescope is also over budget, behind schedule, and it was narrowly saved from cancellation in 2011 amidst further NASA budget cuts.

Hubble and the data it produced may be incredibly valuable scientifically, intellectually, and culturally, but it does not approach the economic or political value of other more tangible technological products, such as the sale of fighter jets or the development of rocket propulsion systems. Although the political and economic justification for space science may be in a weakened state, a significant portion of the public still seem to harbor hope for the civil space program in spite of its perceived failures. A New York Times article written at the end of the space shuttle program addressed the future of NASA:

Hubble is alone now with the stars, its vision as peerless as designed. But America still has no vision at all for its space program, no plan for where to go next or how...I can't blame NASA for that. NASA works for the president, and the president can do only what Congress will give him or her the money for. And Congress answers to the people — that is to say, its campaign contributors. They've all just been doing what they think they have to do, but an astronomer I know who grew up with the same science fiction dreams and expectations as I did once described himself as a member of the "cheated generation."¹⁵⁶

Hubble's deployment was posed at a point in time in which it was able to gain the benefits and navigate the drawbacks of federally funded space science during the Cold War, while embodying the movement away from risky military and prestige-driven space science. As a successful example of large unmanned government funded space science which earned "space spectacular" levels of public engagement, Hubble was in some ways the first program of its kind. In the absence of the socio-political impetus and cultural priorities characteristic of the space race, the

¹⁵⁶ Dennis Overbye, "As Shuttle Era Ends, Dreams of Space Linger," *The New York Times* 4 July 2011.

future of large-scale civilian science programs like Hubble remain precarious as does the structure of the American space program.

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