Section VI

Space History: State of the Art

Introduction

What is the current state of space history as the 21st century commences and the Space Age reaches its 50th anniversary? Is it a vibrant marketplace of ideas and stimulating perspectives? Is it a moribund backwater of historical inquiry with little of interest to anyone and nothing to offer the wider historical discipline? As the four essays in this section demonstrate, space history is at neither extreme of this dichotomy. It has been energized in the last quarter century by a constant stream of new practitioners and a plethora of new ideas and points of view. A fundamental professionalization of the discipline has brought to fruition a dazzling array of sophisticated studies on all manner of topics in the history of spaceflight. Yet, as the collective authors of the section argue, there is much more to be done, and each offers suggestions for how historians might approach the field in new and different ways, each enriching what already exists.

This section opens with an essay by Asif A. Siddiqi assessing the state of U.S. space history. He asserts that scholars have concentrated their work in one of four subfields that collectively may be viewed as making up the whole. As Siddiqi writes, "Some saw the space program as indicative of Americans' 'natural' urge to explore the frontier; some believed that the space program was a surrogate for a larger struggle between good and evil; others wrote of a space program whose main force was modern American technology; and others described a space program whose central actors were hero astronauts, representing all that was noble in American culture." He notes that space history started as a nonprofessional activity undertaken by practitioners and enthusiasts, always viewing the field from the top down and producing an exceptionally "Whiggish" perspective on the past. In the 1980s, the field began to broaden, deepen, and expand through the entry of a number of professionally trained historians who brought new skills and new interests to the subject. A number of pathbreaking works have emerged, especially in the realm of the history of space policy, and the current state of the subdiscipline is vibrant.

Lest space historians become complacent, however, Siddiqi concludes that there is still much to be done. He points to several specific areas that offer tantalizing possibilities for future research. These include studies on political, social, technological, and cultural history using themes and methodologies borrowed from the larger historical community. Good work has already been done, and Siddiqi analyzes some of this work, but many opportunities for additional study are present. Siddiqi expends considerable effort documenting a future research agenda and goes far toward identifying potentially fruitful avenues of research for new scholars seeking entrance into the field.

Siddiqi also comments on the interesting and unusual circumstance of government sponsorship of space history and the possibility that this might taint the published product in some way. Many of the historians working in the field have been sponsored in some measure by NASA, the United States Air Force, or the Smithsonian Institution, either as employees of these entities or as contractors or fellows. What does this connection mean for the work done, Siddiqi asks? Clearly it plays a role, but what role? This issue itself might be a useful avenue of study, relating as it does to the concerns raised in the work of Peter Novick and others about the pursuit of objectivity in historical studies.[1]

For many years, a stigma has existed among some academic historians against sponsored history; such a view is usually misplaced and not a little naive. Those who criticize such work invariably invoke the characterization "court historian" to damn the effort. There are, of course, some instances of influence that all can point to. But the reality is that historical truth is elusive in any setting. Historians usually have a clientele, whether writing for other academic specialists in whatever field is under investigation; or for groups bound together by religion, ethnicity, labor, etc.; or for any number of identifiable groups that have an interest in the subject.[2] Consciously or unconsciously, historians—even if they have not been formally hired to prepare histories for the group—shape their discourses to provide understanding about the past in relationship to ideas already present among those with an interest in the subject. If one strays too far afield from the major streams of understanding about the subject, the historian may be unable to find an outlet for publication, may be censured in reviews, may have his or her livelihood destroyed by not receiving tenure, or may lose whatever reputation he or she had. All of that takes place, even without serving some formal client that may have a vested interest in ensuring that a historian tells a story in a certain way.[3] Still, a study of the influence of government sponsorship on the field of space history would prove a fascinating subject of study.

In chapter 15, Stephen B. Johnson presents a lengthy discussion of the historical study of military space history from the 1950s to the present. In this exhaustive review, Johnson divides his analysis into major sections, conforming to the various missions that the Department of Defense undertakes relative to space operations. After a review of overview sources of military history, the author undertakes an analysis of the development and fielding of intercontinental ballistic missiles (ICBM) and space launchers, which defined the strategic defense capabilities of the United States during the Cold War.

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1. Peter Novick, *That Noble Dream: The "Objectivity Question" and the American Historical Profession* (New York: Cambridge University Press, 1988).

2. See Roger D. Launius, "NASA History and the Challenge of Keeping the Contemporary Past," *Public Historian* 21 (summer 1999): 63–81.

3. See Roger D. Launius, "Mormon Memory, Mormon Myth, and Mormon History," *Journal of Mormon History* 21 (spring 1995): 1–24.

From there, Johnson moves on to discussions of early-warning and space surveillance; command and control; communications; ballistic-missile defense; robotic intelligence and reconnaissance; military human spaceflight; weather and science; navigation; antisatellite and space warfare; organization, management, and acquisition of space systems; and space power theory. Johnson concludes with a gap analysis of "holes in the literature" and offers suggestions for future historical study.

Margaret A. Weitekamp follows with a discussion of how historians working in space history might consider the topic with new "tools" drawn from social and cultural studies. Indeed, one of the most exciting areas of historical inquiry in the last 20 years has been the postmodern analysis of history. Weitekamp acknowledges that richness, which ensures within space history, as it has elsewhere, "the proliferation of subject areas created when historians wrestling with questions of race, class, ethnicity, and gender challenged the artificial nature of the consensus school's master narrative." She then surveys the field, noting important developments in the application of themes in social and cultural studies to the subject of space history, but more importantly, Weitekamp then explores the relationship between space history and this larger discourse. She finds that "space history exists both in 'relation to' other history subdisciplines (a terminology which implies separation from the other subfields and an internal cohesion within space history, two points that deserve questioning in their own right), and in a continually evolving 'relationship with' the rest of the discipline."

Weitekamp also finds that the application of "critical theory" to the history of spaceflight may offer uniquely useful perspectives on the subdiscipline. She defines "critical theory" as "an umbrella term that encompasses the diverse and often divergent theoretical schools of structuralist, poststructuralist, feminist, Marxist, postmodern, and psychoanalytic theory that emerged since the 1970s in literary and anthropological analysis." Already intriguing possibilities for this area have been opened through the work of Jodi Dean, Constance Penley, M. G. Lord, De Witt Douglas Kilgore, and others.[4] Greater use of these methods of historical inquiry has the potential to transform the field of study.

This section closes with an intriguing and stimulating essay by David H. DeVorkin on the importance of the artifact in the study of the history of technology. Most historians, he asserts, do not pay much attention to the objects

4. Jodi Dean, *Aliens in America: Conspiracy Cultures from Outerspace to Cyberspace* (Ithaca, NY: Cornell University Press, 1998); M. G. Lord, *Astro Turf: The Private Life of Rocket Science* (New York: Walker & Co., 2005); De Witt Douglas Kilgore, *Astrofuturism: Science, Race, and Visions of Utopia in Space* (Philadelphia: University of Pennsylvania Press, 2003); Constance Penley, *NASA/TREK: Popular Science and Sex in America* (New York: Verso, 1997).

that they write about. They use quite traditional sources—manuscript materials and other written work—but fail to observe carefully the actual spacecraft, rocket, or other physical object that performed the work under study. He asks the important question, "Are artifacts historical evidence?" Of course they are, he notes, but few historians exploit them effectively in their own work. Perhaps that is because they fail to grasp their significance, but more importantly, it is probably because they do not understand how they work and why they were constructed in the way they were. DeVorkin argues for a greater appreciation of the artifact in the enterprise of historical study and the centrality of it in the narratives fashioned by historians of spaceflight.

Collectively, these four essays point up the richness of the study of the history of the American effort to fly in space since the 1950s. As such, they represent a report from the field of its status and possibilities for the future. Most important, each essay points the direction for future efforts.

Chapter 14

American Space History: Legacies, Questions, and Opportunities for Future Research[1]

Asif A. Siddiqi

In the 35 years since astronauts Neil A. Armstrong and Buzz Aldrin set foot on the Moon, no space achievement has quite captured people's imaginations as Apollo. Thirty-five years after that singular event, the specter of Apollo still looms large as a benchmark for all that came later. In the context of the current inertia of the American space program—the Space Shuttle temporarily grounded while astronauts take to orbit in Russian rockets for unimaginative tours of the International Space Station—Apollo retains an even stronger pull to those seeking adventure and exploration.[2] Given Apollo's centrality in popular conceptions of the history of the space program, it is not surprising that historical writing—both popular and academic—has been shaped profoundly by the experience of the Moon landings. Even those areas of space history that have no apparent connection to Apollo, such as military space history, for example, assume their historical places in our memory in relation to Apollo. Because of the project's status as being emblematic of a lost, young, and adventurous America, space historians negotiating the delicate boundaries between memory and nostalgia have typically veered from the former to the latter with an ease that underscores more about the state of the current space program than the one that actually happened. In addition, Apollo's huge shadow has helped to marginalize many important but unexplored areas of space history.

In the past 40 years of space history, historians have worked within several interpretive approaches to space history, all of them defined and demarcated by the shadow of Apollo and its political backdrop, the Cold War. This essay is an attempt to revisit that historiography in search of some common unify-

1. I would like to thank Dwayne A. Day, Steven J. Dick, Roger D. Launius, and Michael J. Neufeld for their helpful comments.

2. For the current crisis, see Roger D. Launius, "After Columbia: The Space Shuttle Program and the Crisis in Access to Space," *Astropolitics* 2 (July–September 2004): 277–322.

ing themes.[3] The goal is to identify certain interpretive and narrative patterns and then elaborate on areas where scholarship is lacking or where important questions remain unexplored.[4] A close reading of the literature shows that historians have located their work within four different narratives based around exploration, competition, technology, and the astronauts. These interpretive paradigms continue to dominate and define our understanding of the origins, evolution, and nature of the American space program. The categories were not mutually exclusive, and the approaches have overlapped over time, but these four guiding themes have remained as important explanatory devices. Some saw the space program as indicative of Americans' "natural" urge to explore the frontier; some believed that the space program was a surrogate for a larger struggle between good and evil; others wrote of a space program whose main force was modern American technology; and others described a space program whose central actors were hero astronauts, representing all that was noble in American culture.[5]

In all of the four schools, which continue to flourish today, historians have typically examined the history from the top looking down, describing only the tallest trees of a vast forest of society and culture. The first generation of scholarship was distinguished by a focus on linear, narrow, and progress-oriented narratives unencumbered by context, critique, or culture. Historians also shared a nostalgic yearning for the 1960s, the halcyon period of American space exploration. Like the space program itself, historians repeatedly romanticized the claimed victories of Apollo without questioning many of the incontrovertible motivations and repercussions of the space program.

Starting in the 1980s but really coming to fruition in the 1990s, a "new aerospace history" began to emerge. Building on a few notable works published during the late Cold War, a new generation of historians tackled the history of American space exploration from different perspectives involving politics, society, and culture. These new works distinguished themselves from the older canon because they revisited, cajoled, and questioned some of the basic foundational notions of the received space history. Some did so explic-

3. For earlier works on the historiography of American space exploration, see Richard P. Hallion, "A Source Guide to the History of Aeronautics and Astronautics," *American Studies International* 20, no. 3 (1982): 3–50; Hunter A. Dupree, "The History of the Exploration of Space: From Official History to Contributions to Historical Literature," *Public Historian* 8 (1986): 121–128; Pamela E. Mack, "Space History," *Technology and Culture* 30 (1989): 657–665; Roger D. Launius, "The Historical Dimension of Space Exploration: Reflections and Possibilities," *Space Policy* 16 (2000): 23–38.

4. In the paper, I do not distinguish between the often false dichotomy of academic versus popular works. Important contributions to space history have come from both ends of the spectrum, and both have had their strengths and weaknesses. I also do not explore the study of international cooperation in space history, a vast topic covered by others in this volume. Finally, due to limitations of length, I omit discussion of those histories dedicated to the events of the pre-Sputnik era.

5. I list and describe representative examples from each group in the main body of the essay.

itly, others more implicitly. The new history also moved beyond the lenses of competition, exploration, technology, or astronauts. In some cases, the literature built upon the older models, while in others, it made a clean break from the older canon.

Historians also moved into new areas of political, technological, social, and cultural history benefiting from a shared interest in new sources and new methodological approaches. Simultaneously, the old Cold War paradigm of historiography continues to flourish, propagated especially in several syntheses, creating an interpretive tension between the old and new writing that may promote a middle ground in the future. Whether this mix will generate new, interesting, and challenging ideas remains to be seen, but it has been healthy for the field to expand beyond the previously narrow borders, if for nothing else to link and relocate space history, not as something peculiar and unique, but as part of a broader inquiry into American history.

Exploration

The most common motif in space historiography has been that of locating space exploration as part of an eons-long human urge to push the geographical frontiers of existence. Prescriptive works on space exploration published in the pre-Sputnik era—some of which assumed iconic status in later years—firmly established such an approach to history. A harbinger of this paradigm was Willy Ley, a veteran of early amateur German rocketry groups from the 1930s. Updating a book he had first authored in 1944 through 21 printings, Ley's *Rockets, Missiles, and Man in Space* (1968) was a landmark publication that former NASA Chief Historian Roger D. Launius has called "one of the most significant textbooks available in the mid-twentieth century on the possibilities of space travel."[6] A popular historical narrative tracing the evolution of rocket technology from the ancient Babylonians to the mid-1960s, Ley's work weaved together human imperatives and technical evolution in a seamless whole. From the beginning, he described his book as "the story of the idea that we possibly could, and if so should, break away from our planet and go exploring to others, just as thousands of years ago men broke away from their islands and went exploring to other coasts."[7] By focusing on a few scattered, talented individuals with a vision of space travel, Ley delineated the history of space

6. Roger D. Launius, *Frontiers of Space Exploration* (Westport, CT: Greenwood Press, 1998), p. 190; Willy Ley, *Rockets, Missiles, and Men in Space* (New York: Viking Press, 1968). Ley also published an abridged and slightly updated version of his book the following year as *Events in Space* (New York: D. McKay, 1969).

7. Willy Ley, *Rockets: The Future of Travel Beyond the Stratosphere* (New York: The Viking Press, 1945), p. 3. In popular history, others have connected space history to the exploration paradigm. See, for example, Daniel J. Boorstin, *The Discoverers* (New York: Random House, 1983).

exploration as essentially one with an individualistic character. In Ley's world, technology, i.e., the means to fulfill these singular visions, was subordinated to the needs and whims of resourceful scientists or engineers whom he called "Prophets of Some Honor." Thus, the principal actors behind space exploration were neither nations nor states, but noble visionaries. Ley also established a pantheon of icons for the future history of space; by giving currency to such names as Konstantin Tsiolkovskiy, Hermann Oberth, and Robert Goddard, he gave a face to the technology.[8] German rocketry pioneer Wernher von Braun's *History of Rocketry and Space Travel* (1966) (cowritten with Frederick I. Ordway III) built upon Ley's work and cemented a number of unquestioned narratives about the origins of the "Space Age," including the centrality of von Braun's V-2 "rocket team" in the postwar American rocket and space program, thus marginalizing a number of other equally important indigenous innovators in the American context such as the Guggenheim Aeronautical Laboratory at Caltech (GALCIT) and the American Rocket Society.[9] So powerful was this synthesis that to this day, almost all history books on space exploration begin by invoking Tsiolkovskiy, Oberth, and Goddard—and then move to von Braun's rocket team.

What these pioneers had in common was a sustained belief that the human spirit was possessed of an indomitable urge to explore and, as a corollary, to seek knowledge. In one of his most oft-repeated quotes, the Russian theoretician Konstantin Tsiolkovskiy (1857–1935) had written that "the earth is the cradle of reason, but one cannot live in a cradle forever."[10] For the historian of the American space program, reason was combined with a modern version of manifest destiny, a marriage of the near-spiritual urge to explore new frontiers and the cold, hard rationale of technology. One of the earliest scholarly works to equate the idea of the American West with the space fron-

8. For biographies, see Helen B. Walters, *Hermann Oberth: Father of Space Travel* (New York: Macmillan, 1962); Hans Barth, *Hermann Oberth: Vater der Raumfahrt: autorisierte Biographie* (Esslingen: Bechtle, 1991); David A. Clary, *Rocket Man: Robert H. Goddard and the Birth of the Space Age* (New York: Hyperion, 2003); Milton Lehman, *This High Man: The Life of Robert H. Goddard* (New York: Farrar, Straus, 1963); A. Kosmodemiansky, *Konstantin Tsiolkovsky, 1857–1935* (Moscow: Nauka, 1985).

9. Wernher von Braun and Frederick I. Ordway III, *History of Rocketry and Space Travel* (New York: Thomas Y. Cromwell Company, 1966). The book was published in revised editions in 1969, 1975, and 1985. The final edition was published as *Space Travel: A History* (New York: Harper & Row, 1985).

10. K. Tsiolkovskii, "Issledovanie mirovykh prostranstv reaktivnymi priborami (1911–1912 gg.)," in *Izbrannye trudy*, ed. B. N. Vorob'ev and V. N. Sokol'skii (Moscow: Nauka, 1962), p. 196. The original phrase was "Планета есть колыбель разума, но нельзя вечно жить в колыбели," or "*Planeta est' kolybel' razuma, no nel'zia vechno zhit' v kolybeli.*" For typical references to the quote, see A. A. Kosmodemyansky, *K. E. Tsiolkovsky—His Life and Work* (Moscow: Nauka, 1960), p. 153; William Shelton, *Soviet Space Exploration: The First Decade* (New York: Washington Square Press, 1968), pp. 12–13; Roger D. Launius, *Space Stations: Base Camps to the Stars* (Washington, DC: Smithsonian Books, 2003), p. 9.

tier was *The Railroad and the Space Program: An Exploration in Historical Analogy* (1965), a collection of essays which used the American railroad as a metaphor for the slow human migration into space.[11] These early works foreshadowed and exemplified an important thread in the future of space history, equating the American frontier in the West with the space frontier beyond the Earth.

Through the past 50 years, those looking ahead, such as policy-makers and spaceflight advocates from John F. Kennedy to Wernher von Braun to Mars Society President Robert Zubrin, have used Frederick Jackson Turner's frontier motif to inspire, justify, and advocate space exploration on a grand scale.[12] Those looking back, especially space historians, have also invoked the frontier thesis to explain the majesty of the early years of American space exploration; they have explained not only how engagement with the frontier has shaped American society and culture, but also how the foundations of American society and culture—particularly democracy and individualism—have shaped space exploration. The frontier ideal resonated partly because, like space explorers, many of the original explorers of the West shared utopian ideals.[13] The space program represented a potent union of two powerful strands of American culture, the search for utopia and the belief in the power of technology, a manifestation of 20th-century technological utopianism.[14] In the 1960s, at a time when the emerging reevaluation of the frontier thesis and its attendant costs to both the environment and the native peoples of the continent had yet to enter the mainstream discourse in American history, the use of the West as a guiding analogy for space exploration implied expansion, development, freedom, and ultimately liberation from the chains of previous existence. If there were pitfalls in exploration, they were minimal at best.[15] These markers of frontier exploration resonated deeply with many histori-

11. Bruce Mazlish, ed., *The Railroad and the Space Program: An Exploration in Historical Analogy* (Cambridge, MA: MIT, 1965).

12. For Frederick Jackson Turner's original works on the frontier thesis, see John Mack Faragher, ed., *Rereading Frederick Jackson Turner: The Significance of the Frontier in American History and Other Essays* (New Haven, CT: Yale University Press, 1994); George Rogers Taylor, *The Turner Thesis: Concerning the Role of the Frontier in American History*, 3rd ed. (Lexington, MA: Heath, 1972). For the frontier's resonance in modern times, see Richard Slotkin, *Gunfighter Nation: The Myth of the Frontier in Twentieth Century America* (New York: Atheneum, 1992). Roger D. Launius gives some notable examples of prominent advocates invoking the frontier thesis in the 1960s in his "Historical Dimension of Space Exploration."

13. Roger D. Launius, "Perfect Worlds, Perfect Societies: The Persistent Goal of Utopia in Human Spaceflight," *Journal of the British Interplanetary Society* 56 (2003): 338–349.

14. For an excellent look at the origins of technological utopianism in American culture, see Howard P. Segal, *Technological Utopianism in American Culture* (Chicago: University of Chicago Press, 1985).

15. For critiques of the frontier thesis, see Patricia Nelson Limerick, Clyde A. Milner II, and Charles E. Rankin, eds., *Trails: Toward a New Western History* (Lawrence: University Press of Kansas, 1991); Richard White, *It's Your Misfortune and None of My Own: A New History of the American West* (Norman: Oklahoma University Press, 1991).

ans, enough that many still invoke them in the 21st century. Describing the parallel paths of the Russian and American space programs, author Robert Zimmerman, in *Leaving Earth: Space Stations, Rival Superpowers, and the Quest for Interplanetary Travel* (2003), compared them to colonization of Earthly landscapes: "The ancestors of both peoples were pioneers . . . . The land both groups settled was harsh, brutal, and unyielding. Death was omnipresent. Out of these two pioneer struggles have risen nations able to forge in the sky the first rockets, the first spacecraft, and the first tentative and grand attempts to colonize the stars."[16] Similar notions run through Bruce C. Murray's *Journey into Space: The First Three Decades of Space Exploration* (1989) and William E. Burrows's *Exploring Space: Voyages in the Solar System and Beyond* (1990), both of which explicitly deal with deep space exploration by robotic probes.[17] That Earthly exploration remains a powerful motif for making sense of space exploration is exemplified best by *Where Next, Columbus? The Future of Space Exploration* (1994), a collection of meditations by prominent historians that link Columbus's seabound trip to the early years of space exploration.[18]

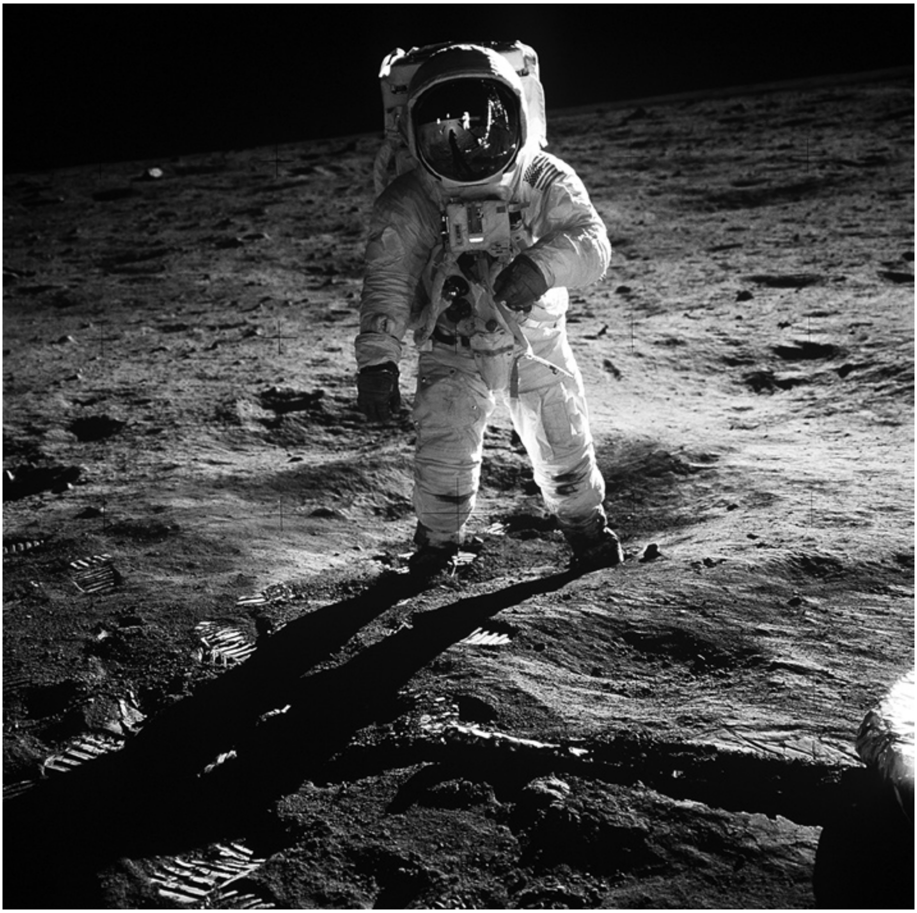
Once the landing of Apollo astronauts on the Moon in July 1969 effectively ended the "space race" for the United States, historians took up the challenge of chronicling this extraordinary technological achievement in a multitude of works, many of which framed the project as part of the human exploration imperative. Unlike many other programs of the 1960s, or indeed since, the Apollo program represented a perfect distillation of interpretive approaches that focused on exploration since the Apollo missions had geographical delimiters that paralleled exploration of the West: beginning from the known, the Earth, voyagers set out in a very physical way for the unknown, the Moon. In contrast, the hundreds of Earth-orbital missions since 1972, while risky and adventurous, have not represented physical movement in the same way Apollo did.[19] NASA managers early on recognized Apollo's exceptionalist nature within the space program. In the introduction to one of the first volumes to reflect on Apollo, then–NASA Administrator James C. Fletcher explicitly located the Apollo expeditions as part of a tradition stretch-

16. Robert Zimmerman, *Leaving Earth: Space Stations, Rival Superpowers, and the Quest for Interplanetary Travel* (Washington, DC: Joseph Henry Press, 2003), p. 460.

17. Bruce C. Murray, *Journey into Space: The First Three Decades of Space Exploration* (New York: W. W. Norton, 1989); William E. Burrows, *Exploring Space: Voyages in the Solar System and Beyond* (New York: Random House, 1990).

18. Valerie Neal, ed., *Where Next, Columbus? The Future of Space Exploration* (New York: Oxford University Press, 1994). See also Peter Bond, *Reaching for the Stars: An Illustrated History of Manned Spaceflight*, 2nd ed. (London: Cassell, 1996).

19. Deam argues that "this shift has essentially emptied the [space] program of its public character, moving spaceflight from an open embrace of political action to closed concerns with economics and technological determinism" (Dirk Deam, "Public Space: Exploring the Political Dimensions of the American Space Program" [Ph.D. diss., University of Iowa, 1999]).



Since the time of the Apollo 11 Moon landing in 1969, space history has matured into a much more rigorous and complex area of study, one with which the theme of exploration has long been associated. No photograph better illustrates this connection than the image of Buzz Aldrin on the Moon. It has assumed iconic proportions in modern society. *(NASA image no. AS11-40-5903)*

ing back to the Pilgrims at Plymouth and Darwin's voyages on the HMS *Beagle*; both were "ventures into uncharted waters."[20] Similarly, Harry Hurt III, in his *For All Mankind* (1988), compared the Apollo missions to Earthly explorations, specifically invoking "Christopher Columbus's daring voyage to the New World."[21]

20. James C. Fletcher, "Foreword," in *Apollo Expeditions to the Moon*, ed. Edgar M. Cortright (Washington, DC: NASA, 1975).

21. Harry Hurt III, *For All Mankind* (New York: The Atlantic Monthly Press Book, 1988), p. xiii.

Beyond linking the great Earthly explorations and migrations with the Apollo expeditions, early works on Apollo, such as the Apollo 11 astronauts' (ghostwritten) *First on the Moon* (1970) and Richard Lewis's *The Voyages of Apollo: The Exploration of the Moon* (1974), focused predominantly on the people at the tip of the iceberg, i.e., the astronauts who performed the missions.[22] Two decades later, Andrew Chaikin's landmark *A Man on the Moon* (1994) continued in this vein, merging the exploration motif with the astronauts' perspectives on the project while omitting any interpretive look at the broader political, social, or cultural factors behind Apollo.[23] By focusing exclusively on the thoughts of the astronauts, the details of the missions, and the nuances of the technology, Chaikin masterfully conveyed the experience of Apollo as if it were one in which only a few dozen people were involved. Context was provided only to the extent that the news media reported it at the time of the Apollo missions.[24] Thus, in one sense, in the historiography of the space program, Apollo became a national, even global experience that was conceived, executed, and directly experienced by a few chosen ambassadors. This contradiction may not be as irreconcilable as it appears, for Apollo was a unique artifact of its time. Millions of people witnessed the first landing of humans on another celestial body through their black-and-white TVs in the comfort of their homes. Such vicarious exploration had no precedent. If the import of Apollo was ultimately global, signaling human migration off the planet, then its immediate communicative power was ultimately largely private, in homes and offices.

Historically, many of those who advocated space exploration emphasized science as an important rationale for exploration. The literature on the history of space-based science has, however, not been significant. Several factors explain the weakness of a unified tradition of writing on space science history. These include the fragmentary nature of the field, where much of the work is generated from other history-of-science subdisciplines such as the history of physics, astronomy, life sciences, meteorology, and oceanography. The contributions in two volumes of essays separated by 10 years, *Space Science Comes of Age: Perspectives in the History of the Space Sciences* (1981) and *A Spacefaring Nation: Perspectives on American Space History and Policy* (1991), underline the difficult struggles of nascent space-based science constituencies (within solar science and planetary science) to escape the shadow of their parent communi-

22. Neil Armstrong, Michael Collins, and Edwin E. Aldrin, Jr., with Gene Farmer and Dora Jane Hamblin, *First on the Moon* (Boston: Little, Brown, and Company, 1970); Richard S. Lewis, *The Voyages of Apollo: The Exploration of the Moon* (New York: Quadrangle, 1974).

23. Andrew Chaikin, *A Man on the Moon: The Voyages of the Apollo Astronauts* (New York: Viking, 1994).

24. For media treatments of the space program, see Andrew A. Klyukovski, "The Space Race as the American Dream: Fantasy Theme Analysis of 'The New York Times' Coverage" (Ph.D. diss., University of Missouri-Columbia, 2002).

ties (physics and astronomy).[25] Additionally, science has traditionally played a secondary (if not tertiary) role in the American space program, behind political and military imperatives. For space historians who have chronicled the American space program as political, nationalistic, or technological enterprises, space science has been a corollary theme rather than a central one.[26] Two volumes of NASA's *Exploring the Unknown* series chronicling the history of American civilian space exploration are the most important contributions to space science history, but the editors' consignment of space sciences to volumes 5 and 6 in the series underscores the subfield's priority in the schematic of space history overall.[27] Finally, historians have frequently seen space science as deeply connected to rationales of militarization or exploration. As such, space science history remains embedded with these other narratives. For example, in his *Science with a Vengeance: How the Military Created the US Space Sciences after World War II* (1992), David DeVorkin argued that space science was created largely due to the existence of the German V-2 missile, a weapon of war whose development had nothing to do with either the search for scientific knowledge or exploration.[28]

25. Paul A. Hanle and Del Chamberlain, eds., *Space Science Comes of Age: Perspectives in the History of Space Sciences* (Washington, DC: Smithsonian Institution Press, 1981). See also Karl Hufbauer, "Solar Observational Capabilities and the Solar Physics Community Since Sputnik, 1957–1988"; Joseph N. Tatarewicz, "Space Technology and Planetary Science, 1950–1985," in *A Spacefaring Nation: Perspectives on American Space History and Policy*, eds. Martin J. Collins and Sylvia D. Fries (Washington, DC: Smithsonian Institution Press, 1991), pp. 77–114, 115–132.

26. Two important works on science performed during Apollo are framed as part of programmatic "mission-oriented" histories. See William David Compton, *Where No Man Has Gone Before: A History of Apollo Lunar Exploration Missions* (Washington, DC: NASA SP-4214, 1989); David M. Harland, *Exploring the Moon: The Apollo Expeditions* (London: Springer, 1999). A third, lesser-known but more accomplished work focuses exclusively on the science rather than the missions: Donald A. Beattie, *Taking Science to the Moon: Lunar Experiments and the Apollo Program* (Baltimore: Johns Hopkins, 2001).

27. See particularly the excellent introductory essays in John M. Logsdon, ed., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. 5, *Exploring the Cosmos* (Washington, DC: NASA SP-2001-4407, 2001); John M. Logsdon et al., eds., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. 6, *Space and Earth Science* (Washington, DC: NASA SP-2004-4407, 2004). For the few other notable works on the history of space science, see Charles A. Lundquist, *Skylab's Astronomy and Space Sciences* (Washington, DC: NASA, 1979); John A. Pitts, *The Human Factor: Biomedicine in the Manned Space Program to 1980* (Washington, DC: NASA SP-4213, 1985; John E. Naugle, *First Among Equals: The Selection of NASA Space Science Experiments* (Washington, DC: NASA SP-4215, 1991); David Leverington, *New Cosmic Horizons: Space Astronomy from the V-2 to the Hubble Space Telescope* (New York: Cambridge University Press, 2001).

28. David H. DeVorkin, *Science with a Vengeance: How the Military Created the US Space Sciences after World War II* (New York: Springer-Verlag, 1992); David H. DeVorkin, "Military Origins of the Space Sciences in the American V-2 Era," in *National Military Establishments and the Advancement of Science and Technology*, eds. Paul Forman and José M. Sánchez-Ron, Studies in Twentieth Century History (Boston: Kluwer Academic Publishers, 1996). See also DeVorkin's "Solar Physics," in *Exploring the Unknown*, vol. 6, pp. 1–37.

Competition and National Security

The exploration motif overlaps with a second theme running through the historiography of space exploration, that of competition. Richard Lewis, in his *From Vinland to Mars: A Thousand Years of Exploration* (1976), eloquently illustrated the ways in which competition over resources and land spurred exploration. He found a common imperative existing from the Greenland and Vinland voyages of the Viking Eric the Red all the way to the Viking spacecraft landings on Mars in the bicentennial year of 1976. Framing his narrative around this coincidence of names, Lewis focused on competition as a guiding metaphor for space exploration:

> The common denominator [in all exploration] is intraspecific competition . . . : deadly competition among men and families for land, among nations for power and wealth. This is the force that drove the have-nots in medieval Scandinavia across uncharted seas, impelled Renaissance Europe to seek the wealth of the Indies and circumnavigate the planet, urged Amundsen and Scott on the tragic race to the geographic south pole, and launched Americans to the Moon.[29]

Like Lewis, many space historians have used competition—specifically, the Cold War—as a second defining lens to understand space history. Most popular accounts of the space race, and many from an academic perspective, have framed the American adventure in space as competition with an adversary who did not share the same moral commitment to freedom and equality. In the canon, both Sputnik and Apollo emerge, at least implicitly, as material representations embedded with notions of two ideologically opposed systems of governance. To a large degree, such evaluations of Apollo reflected rhetoric from the 1960s—from American politicians, the American media, and from participants in the Apollo project itself. But because accounts of the space race have been typically undergirded by implicit claims about morality of national cultures, historians rarely engaged in critiques of Apollo or the space program in general, since such methodological approaches would be tantamount to challenging the moral authority of the United States. In his recent *Apollo: The Epic Journey to the Moon*, an engaging and awe-inspiring account of the Apollo project, David West Reynolds distills this rationale succinctly and emotionally:

29. Richard S. Lewis, *From Vinland to Mars: A Thousand Years of Exploration* (New York: Quandrangle, 1976), p. xii.

> [The Moon race] was a Cold War battle to demonstrate the superior ability of the superior system, capitalism versus communism . . . . And the battle did prove out the more capable system . . . . The reasons are many, but among them the power of free enterprise ranks high . . . . Free competition motivated American workers whose livelihoods were related to the quality and brilliance of their work, and we saw extraordinary, impossible things accomplished by ordinary Americans. The American flag on the Moon is such a powerful symbol because it is not a vain one. America, like no other nation, *was* capable of the Moon.[30]

Beyond linking Cold War competition to celebratory nationalistic impulses, others used competition to revisit seminal events in space history. John M. Logsdon's *The Decision to Go to the Moon: Project Apollo and the National Interest* (1970), the classic study of the original imperatives that gave rise to Apollo, was one of the earliest.[31] Kennedy's actual decision to go to the Moon stemmed from a series of politically inopportune precipitates, including the aborted Bay of Pigs invasion and Yuri Gagarin's historic first flight into space in April 1961. Keen to respond to the unending humiliations in the new space frontier, Kennedy enlisted the aid of Vice President Lyndon B. Johnson to formulate an ambitious but realistic response to the Soviets. By the end of May, after extensive consultations with their advisers, Kennedy and Johnson had their goal: send Americans to the Moon before the end of the decade, an announcement the President made to a joint session of Congress on 25 May 1961. By synthesizing the disparate threads of the events of 1961 using primary documentation, Logsdon laid the groundwork for understanding a seminal event in U.S. space policy and thus built the foundation for a new interpretive school of space history, space *policy* history.[32]

Cold War competition has loomed large in the vast subgenre of space policy history, and a number of works have sought to explain the twists and turns of American space policy through its interdependence with Cold War

30. David West Reynolds, *Apollo: The Epic Journey to the Moon* (New York: Tehabi, 2002), p. 257.

31. John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge, MA: MIT Press, 1970).

32. For collections that include essays on the history of space policy, see Radford Byerly, Jr., ed., *Space Policy Reconsidered* (Boulder, CO: Westview Press, 1989); Radford Byerly, Jr., ed., *Space Policy Alternatives* (Boulder, CO: Westview Press, 1992); Roger D. Launius, ed., *Organizing for the Use of Space: Historical Perspectives on a Persistent Issue* (San Diego: Univelt, 1995); Eligar Sadeh, ed., *Space Politics and Policy: An Evolutionary Perspective* (Dordrecht, Netherlands: Kluwer Academic Publishers, 2003).

politics on an international scale.[33] The results of several history conferences in the 1980s—hosted by NASA and the National Air and Space Museum—broke new ground in the field of space policy history by going beyond the original Cold War competition dynamic.[34] A number of these papers departed from much of the early historiography by focusing on post-Apollo efforts including the space station *Freedom* and the Hubble Space Telescope. In exploring, for example, how NASA's Space Station Task Force convinced a lukewarm White House to support the original *Freedom* proposal in the early 1980s, Howard McCurdy highlighted the influence of government agencies over governmental policy.[35] Others explored the dynamics of space policy through specific presidential administrations, thus analyzing the causes why some space projects survive and others don't, depending on politics at the highest level.[36]

A number of space policy histories took an overtly critical stance to NASA and its mission, focusing often on the lack of foresight exhibited by policy-makers and managers at NASA, the Congress, and the Executive Branch.[37] Amitai Etzioni's *The Moon Doggle: Domestic and International Implications of the Space Race* (1964), although not a history book, was one such early critique which called the entire enterprise of Apollo into doubt since he believed that

33. See, for example, William H. Schauer, *The Politics of Space: A Comparison of the Soviet and American Space Programs* (New York: Holmes & Meier Publishers, 1976); Xavier Pasco, *La Politique Spatiale des Etats-Unis: 1958–1995: Technologie, inérêt national et débat public* (Paris: L'Harmattan, 1997); Matthew J. Von Bencke, *The Politics of Space: A History of U.S.-Soviet/Russian Competition and Cooperation in Space* (Boulder, CO: Westview Press, 1997); Dale L. Hayden, *The International Development of Space and Its Impact on U.S. National Space Policy* (Maxwell AFB, AL: Airpower Research Institute, College of Aerospace Doctrine, Research and Education, Air University, 2004).

34. For the proceedings of the 1981 and 1987 conferences, see Hanle and Chamberlain, *Space Science Comes of Age*; Collins and Fries, *Spacefaring Nation*. The proceedings of a similar conference hosted by Yale University in 1981 were published as Alex Roland, ed., *A Spacefaring People: Perspectives on Early Spaceflight* (Washington, DC: NASA SP-4405, 1985).

35. Howard E. McCurdy, "The Space Station Decision: Politics, Bureaucracy, and the Making of Public Policy," in *Spacefaring Nation*, ed. Collins and Fries, pp. 9–28.

36. Linda T. Krug, *Presidential Perspectives on Space Exploration: Guiding Metaphors From Eisenhower to Bush* (New York: Praeger, 1991); Derek W. Eliott, "Finding an Appropriate Commitment: Space Policy Development Under Eisenhower and Kennedy, 1954–1963" (Ph.D. diss., George Washington University, 1992); Howard E. McCurdy, *The Space Station Decision: Incremental Politics and Technological Choice* (Baltimore: Johns Hopkins, 1990); Mark Damohn, *Back Down to Earth: The Development of Space Policy for NASA During the Jimmy Carter Administration* (San Jose, CA: Authors Choice Press, 2001).

37. Erik Bergaust, *Murder on Pad 34* (New York: Putnam, 1968); Erlend A. Kennan and Edmund H. Harvey, Jr., *Mission to the Moon: A Critical Reexamination of NASA and the Space Program* (New York: Morrow, 1969); Hugo Young, Brian Silcock, and Peter Dunn, *Journey to Tranquillity: The History of Man's Assault on the Moon* (London: Cape, 1969); Roger Handberg, *Reinventing NASA: Human Spaceflight, Bureaucracy and Politics* (Westport, CT: Praeger, 2003); Greg Klerkx, *Lost in Space: The Fall of NASA and the Dream of a New Space Age* (New York: Pantheon Books, 2004).

it represented a cynical public relations exercise diverting attention away from more pressing domestic issues such as the War on Poverty.[38]

Since the mid-1980s, a number of important works used the Cold War competition paradigm but focused specifically on national security programs, which constituted about half of all national expenditures on spaceflight yet received relatively little scrutiny from historians. The earliest academic work in this subfield was Paul B. Stares's *The Militarization of Space: U.S. Policy, 1945–1984* (1985), which examined the rise of the American space weapons program and its largely unrecorded but substantial influence over American military policy.[39] Writing during a time of extreme tension between the Soviet Union and the United States, Stares argued that the arms race was migrating to the arena of space by the mid-1980s. Equally groundbreaking was journalist William E. Burrows's *Deep Black: Space Espionage and National Security* (1986), in which he focused on the development of highly classified photoreconnaissance satellites which spy on other nations. Using anonymous sources and declassified materials, he wove a story of a secret world that in fact consumed a substantial share of the American space budget but whose very existence was never explicitly acknowledged by the U.S. government.[40]

The early work of Stares and Burrows was overshadowed by CIA-sponsored post–Cold War declassification initiatives. In 1995, the U.S. government revealed details of one of the biggest secrets of the Cold War, the United States' first operational spy satellite system, CORONA, whose satellites flew dozens of missions in the 1960s over secret targets in the Soviet Union, China, Vietnam, and elsewhere. If earlier writing on the genesis of the U.S. space effort emphasized civilian programs such as Vanguard and Explorer, the CORONA revelations helped to reframe the early years of the American space program as parallel and sometimes interconnected civilian and military

38. Amitai Etzioni, *The Moon Doggle: Domestic and International Implications of the Space Race* (Garden City, NY: Doubleday, 1964). For other contemporary works, see Edwin Diamond, *The Rise and Fall of the Space Age* (Garden City, NY: Doubleday, 1964); Vernon van Dyke, *Pride and Power: The Rationale of the Space Program* (Urbana: University of Illinois Press, 1964).

39. Paul B. Stares, *The Militarization of Space: U.S. Policy, 1945–1984* (Ithaca: Cornell University Press, 1985). I differentiate here between military space programs and intelligence space programs, both of which fall under national security programs. The former include weapons development, while the latter include reconnaissance satellites. The earliest open work to explore the American military and intelligence space programs was Phillip Klass's *Secret Sentries in Space* (New York: Random House, 1971). Anthony Kenden was another pioneering scholar in the field. See his "U.S. Reconnaissance Satellite Program," *Journal of the British Interplanetary Society* (July 1978), and "A New U.S. Military Space Mission," *Journal of the British Interplanetary Society* (October 1982).

40. William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Berkley Books, 1986). For a Cold War–era look at space weaponization, see Curtis Peebles, *Battle for Space* (Dorset, U.K.: Blandford, 1983). Another important contribution in the pre-CORONA-revelation era was Jeffrey T. Richelson's *America's Secret Eyes in Space: The U.S. Keyhole Spy Satellite Program* (New York: Harper & Row, 1990).

projects. Where civilian efforts, especially the human spaceflight program, had assumed center stage in the historiography, CORONA highlighted how much of the old history had told only half the story. The CIA's first deputy director for science and technology, Albert D. "Bud" Wheelon, who managed the CORONA program in the mid-1960s, wrote in *Eye in the Sky: The Story of the CORONA Spy Satellites* (1998):

> When the American government eventually reveals the full range of reconnaissance systems developed by this nation, the public will learn of space achievements every bit as impressive as the Apollo moon landings. One program proceeded in utmost secrecy, the other on national television. One steadied the resolve of the American public; the other steadied the resolve of American presidents.[41]

Photoreconnaissance satellite programs such as CORONA and its successors, such as the KH-9 HEXAGON and KH-11 KENNAN, consumed a lion's share of the U.S. "black" space program and, in fact, drove much of early U.S. space policy. Historical details of other important programmatic elements of American national security projects, such as early-warning systems, signals intelligence, military communications, meteorology, navigation, antisatellite, and (abandoned) human military spaceflight projects, have come to light owing to the research of several historians including R. Cargill Hall, Jeffrey T. Richelson, and Dwayne A. Day, whose works represented a major shift in the scholarship on military space programs, moving from speculative works based on rumor, leaks, and analysis of orbital parameters to using primary documentation.[42] Day's work has been particularly groundbreaking, opening up previ-

41. Albert D. Wheelon, "CORONA: A Triumph of American Technology," in *Eye in the Sky: The Story of the CORONA Spy Satellites*, ed. Dwayne A. Day et al. (Washington, DC: Smithsonian Institution Press, 1998), p. 38.

42. For a discussion of early warning, see Jeffrey T. Richelson, *America's Space Sentinels: DSP Satellites and National Security* (Lawrence: University Press of Kansas, 1999); R. Cargill Hall, "Missile Defense Alarm: The Genesis of Space-Based Infrared Early Warning," *Quest: The History of Spaceflight Quarterly* 7, no. 1 (1999): 5–17. For naval strategy and military space programs, see Norman Friedman, *Seapower and Space: From the Dawn of the Missile Age to Net-Centric Warfare* (Annapolis, MD: Naval Institute Press, 2000). For manned military programs, see Roy F. Houchin II's "Why the Air Force Proposed the Dyna-Soar X-20 Program" and "Why the Dyna-Soar X-20 Program Was Cancelled," both in *Quest: The History of Spaceflight Magazine* 3, no. 4 (1994): 5–12 and 35–37, respectively; Steven R. Strom, "The Best Laid Plans: A History of the Manned Orbiting Laboratory," *Crosslink* 5, no. 2 (2004): 11–15. For weather satellite programs, see Dwayne A. Day, "Dark Clouds: The Classified Origins of the Defense Meteorological Satellite Program," *Spaceflight* 43 (2001): 382–385; R. Cargill Hall, "A History of the Military Polar Orbiting Meteorological Satellite Program," *Quest: The History of Spaceflight Quarterly* 9, no. 2 (2002): 4–25. For navigation satellites, see Bradford W. Parkinson et al., "A History of Satellite Navigation," *Navigation: Journal*

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ously hidden aspects of geodetic, signals intelligence, and photoreconnaissance satellite projects.[43] His recent work on the Air Force's interest in developing a dual human space capsule and reconnaissance satellite in the late 1950s adds to our understanding of the motivations and strategies institutions used to achieve specific goals in the early days of space exploration.[44]

This substantive (and generational) shift in scholarship, made possible by post–Cold War declassifications, has allowed the study of American military space history to focus on questions common to the study of American military history and intelligence collection, such as civil-military relations, interservice and interorganizational rivalry, and the relationship between technological development and mission requirements. Day, for example, produced important scholarship on the uses of satellite intelligence in monitoring the supersecret Soviet human lunar landing project in the 1960s, thus illuminating the hitherto unknown ways in which the civilian NASA interacted with the intelligence community.[45] Richelson's groundbreaking *The Wizards of Langley* (2001), a history of the CIA's Directorate of Science and Technology which developed and deployed both photoreconnaissance and signals intelligence systems during the Cold War, also exemplifies this new generation. Weaving

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of the Institute of Navigation 42, no. 1, special issue (1995): 109–164; Chris Banther, "A Look into the History of American Satellite Navigation," *Quest: The History of Spaceflight Quarterly* 11, no. 3 (2004): 40–48. For antisatellite projects, see Wayne R. Austerman, *Program 437: The Air Force's First Antisatellite System* (Peterson AFB, CO: Office of History, 1991); Dwayne A. Day, "Arming the High Frontier," *Spaceflight* 46 (2004): 467–471. For organizational histories, see Harold M. Sapolsky, *Science and the Navy: The History of the Office of Naval Research* (Princeton: Princeton University Press, 1990); David N. Spires, *Beyond Horizons: A Half Century of Air Force Space Leadership* (Peterson AFB: Air Force Space Command, 1997); James Bamford, *Body of Secrets: Anatomy of the Ultra-Secret National Security Agency* (New York: Anchor Books, 2001); Jeffrey T. Richelson, *The Wizards of Langley: Inside the CIA's Directorate of Science and Technology* (Boulder, CO: Westview Press, 2001). For command and control, see David C. Arnold, *Spying from Space: Constructing America's Satellite Command and Control Systems* (College Station: Texas A&M University Press, 2005).

43. Day has published a series of articles on these topics. For geodetic projects, see "Mapping the Dark Side of the World: Part 1: The KH-5 ARGON Geodetic Satellite" and "Mapping the Dark Side of the World: Part 2: Secret Geodetic Programmes after ARGON," both in *Spaceflight* 40 (1998): 264–269 and 303–310, respectively. For signals intelligence satellites, see "Tinker, Tailor, Radar, Spy: Early American Ferret and Radar Satellites," *Spaceflight* 43 (2001): 288–293; "Ferrets Above: American Signals Intelligence Satellites During the 1960s," *International Journal of Intelligence and Counterintelligence* 17, no. 3 (2004): 449–467. For photoreconnaissance, see "A Sheep in Wolf's Clothing: The Samos E-5 Recoverable Satellite, Part 1," *Spaceflight* 44 (2002): 424–431; "A Square Peg in a Cone-Shaped Hole: The Samos E-5 Recoverable Satellite, Part 2," *Spaceflight* 45 (2003): 71–79; "From Cameras to Monkeys to Men: The Samos E-5 Recoverable Satellite, Part 3," *Spaceflight* 45 (2003): 380–389.

44. Day, "From Cameras to Monkeys to Men."

45. Dwayne A. Day and Asif A. Siddiqi, "The Moon in the Crosshairs: CIA Intelligence on the Soviet Manned Lunar Programme," *Spaceflight* 45 (2003): 466–475 and 46 (2004): 112–125; Dwayne A. Day, "From the Shadows to the Stars: James Webb's Use of Intelligence Data in the Race to the Moon," *Air Power History* 51, no. 4 (winter 2004): 30–39. See also Roger D. Launius, "NASA Looks to the East: American Intelligence Estimates of Soviet Capabilities and Project Apollo," *Air Power History* (fall 2001): 5–15.

an intricate story of various projects that "represented a quantum leap in U.S. intelligence capabilities," he locates the development of these systems in a broader context involving relationships with influential scientists outside the agency, the necessity to fill gaps in intelligence collection, and the connections between satellite development and intelligence production.[46]

The two most important works on CORONA, Day et al.'s *Eye in the Sky* and McDonald's *CORONA*, included contributions from individuals who participated in CORONA development in the late 1950s and early 1960s; as such, they can be characterized as semiofficial histories.[47] Both unequivocally extolled the technological, managerial, and operational successes of the project. Its history was framed as part of a singularly powerful story about the efficacy of good management and high technology to benefit the national interest of the United States, which was synonymous with engendering peace and freedom abroad. Writing about CORONA's use in monitoring compliance with arms control agreements, historian Ernest R. May concluded his essay by suggesting that "probably . . . the best one-line epitaph for CORONA would read: 'It helped keep peace in the nuclear age'."[48]

The end of the Cold War—specifically the collapse of the Soviet empire—validated, to some degree, the moral ground for historians writing of American military space programs. The writing on CORONA echoed a powerful strand of post-1991 historiography of the Cold War in general, which celebrated American motives over ideologically and morally suspect Soviet intentions. The post–Cold War self-congratulatory climate insulated the history of CORONA or other U.S. military space programs from critiques of their relationship to the Cold War military-industrial complex or

46. Richelson, *Wizards of Langley*, p. 287. For a poor example of the "new" history—on the understudied topic of intelligence analysis—see David T. Lindgren, *Trust But Verify: Imagery Analysis in the Cold War* (Annapolis, MD: Naval Institute Press, 2000). For civil-military interactions, see John Cloud, "Imaging the World in a Barrel: CORONA and the Clandestine Convergence of the Earth Sciences," *Social Studies of Science* 31, no. 2 (2001): 231–251; John Cloud, "Re-Viewing the Earth: Remote Sensing and Cold War Clandestine Knowledge Production," *Quest: The History of Spaceflight Quarterly* 8, no. 2 (2001): 4–16; Ronald E. Doel, "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in USA After 1945," *Social Studies of Science* 33, no. 5 (2003): 635–666.

47. Day et al., *Eye in the Sky*; Robert McDonald, ed., *CORONA: Between the Sun & the Earth: The First NRO Reconnaissance Eye in Space* (Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 1997). For derivative works based on the above, see Curtis Peebles, *The Corona Project: America's First Spy Satellites* (Annapolis, MD: Naval Institute Press, 1997); Philip Taubman, *Secret Empire: Eisenhower, the CIA, and the Hidden Story of America's Space Espionage* (New York: Simon & Schuster, 2003). For an overview of the literature on CORONA, see Dwayne A. Day, "Rashomon in Space: A Short Review of Official Spy Satellite Histories," *Quest: The History of Spaceflight Quarterly* 8, no. 2 (2000): 45–53.

48. Ernest R. May, "Strategic Intelligence and U.S. Security: The Contributions of CORONA," in *Eye in the Sky*, p. 28.

as part of American interventionist aims in global conflicts played out in the developing world (in, for example, Southeast Asia and Central America).[49]

While the contextual touchstone of U.S. military space history is the Cold War, the literature has remained woefully disconnected from many of the broader intellectual debates that have characterized the historiography of the Cold War through the past 40 years and now in the post–Cold War era. Beginning with the historians who defended the policy of containment against expansionist Soviet intentions, to the generation of revisionists who argued the left-liberal position that American economic interests on a global level contributed to the Cold War, to the postrevisionists who emphasized misperception and misunderstanding to explain much of the Cold War, the canon has passed through many transformations.[50] From the 1980s, and especially in the post–Cold War period, several new threads emerged as diplomatic, social, and cultural historians contributed richly to understanding not only international relations, but also domestic American cultural currents that formed part of the mosaic of the country's trajectory through the Cold War. For example, a new generation of historians is now looking at how domestic culture affected foreign policy.[51]

In terms of international competition—the principal context for the origins of the American space program—the biggest public splash was made by John Lewis Gaddis's *We Know Now: Rethinking Cold War History* (1997), which harked back to the original view that Stalin's personality, Soviet authoritarianism, and communist ideology were principal reasons for the Cold War.[52]

49. For a rare example on the strategic dimension of space support during wartime, see Henry W. Brandli, "The Use of Meteorological Satellites in Southeast Asia Operations," *Aerospace Historian* 29, no. 3 (1982): 172–175.

50. For useful summaries of the enormous transformations in Cold War historiography, see Melvyn P. Leffler, "The Cold War: What Do 'We Know Now'?" *American Historical Review* 104, no. 2 (1999): 501–524; Timothy J. White, "Cold War Historiography: New Evidence Behind Traditional Typographies," *International Social Science Review* 1, no. 1 (fall–winter 2000).

51. David Campbell, *Writing Security: United States Foreign Policy and the Politics of Identity* (Minneapolis: University of Minnesota Press, 1992); Brenda Gayle Plummer, *Rising Wind: Black Americans and U.S. Foreign Affairs, 1935–1960* (Chapel Hill: University of North Carolina Press, 1996); Akira Iriye, *Cultural Internationalism and World Order* (Baltimore: Johns Hopkins, 1997); Frank Costigliola, "'Unceasing Pressure for Penetration': Gender, Pathology, and Emotion in George Kennan's Formation of the Cold War," *Journal of American History* 84 (1997): 1309–1339; Robert D. Dean, "Masculinity as Ideology," *Diplomatic History* 22 (1998): 29–62.

52. John Lewis Gaddis, *We Know Now: Rethinking Cold War History* (Oxford: Clarendon Press, 1997). See also Gaddis, "Rethinking Cold War History: A Roundtable Discussion," in *At the End of the American Century: America's Role in the Post–Cold War World*, ed. Robert L. Hutchins (Baltimore: Johns Hopkins, 1998), pp. 52–66; Douglas J. Macdonald, "Communist Bloc Expansion in the Early Cold War: Challenging Realism, Refuting Revisionism," *International Security* 20 (1995–1996): 152–188. For similar perspectives on the Soviet side, see Vladislav Zubok and Constantine Pleshakov, *Inside the Kremlin's Cold War: From Stalin to Khrushchev* (Cambridge, MA: Harvard University Press, 1996); Vojtech Mastny, *The Cold War and Soviet Insecurity: The Stalin Years* (New York: Oxford University Press, 1996).

Gaddis's arguments were countered by many who emphasized and explored ideology on both sides, the organization of overseas propaganda by both governments, transnational global relations, the relationship between military capabilities and diplomatic policies, the end of colonialism, and conflicts played out between "strong" and "weak" powers.[53] Military space historians whose objects of study are firmly embedded in the Cold War have yet to evolve through these larger debates. The recent works on CORONA, for example, implicitly and closely follow the "Gaddis school," remaining disconnected from equally compelling but entirely different narratives of the history of the Cold War.[54] In *The Devil We Knew: Americans and the Cold War* (1993), respected diplomatic historian H. W. Brands argued that the battle with the Soviet Union served a spectrum of psychological, economic, strategic, and political imperatives. He claimed that the United States subverted some of the nation's best principles to win the Cold War. Thus any proclaimed victory was, at best, ambiguous.[55] How does the success of CORONA fit into such thinking? We may have much to learn from an exploration of this question.

Artifactual and Programmatic Histories

Beyond exploration and competition, a third large body of space history represents history centered on artifacts and/or programs. Willy Ley's early works—as well as those of David Lasser, Chas G. Philp, and P. E. Cleator—pioneered the artifact-centered history by merging the canon of popular science with popular history.[56] This school focused mainly on explaining how particu-

53. See for example, Thomas Borstelmann, *Apartheid's Reluctant Uncle: The United States and Southern Africa in the Early Cold War* (New York: Oxford University Press, 1993); Robert J. McMahon, *The Cold War on the Periphery: The United States, India, and Pakistan* (New York: Columbia University Press, 1994); David Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy, 1939–1954* (New Haven, CT: Yale University Press, 1994); Thomas Risse-Kappen, *Cooperation Among Democracies: The European Influence on U.S. Foreign Policy* (Princeton, NJ: Princeton University Press, 1995); Ilya Gaiduk, *The Soviet Union and the Vietnam War* (Chicago: I. R. Dee, 1996); Steven J. Zaloga, *The Kremlin's Nuclear Sword: The Rise and Fall of Russia's Strategic Nuclear Forces, 1945–2000* (Washington, DC: Smithsonian Institution Press, 2002).

54. For a balanced view of American military space policy within the broader international context, see Michael E. O'Hanlon, *Neither Star Wars nor Sanctuary: Constraining the Military Uses of Space* (Washington, DC: The Brookings Institution, 2004). The few explicit critiques of the U.S. military space program, unfortunately, have been shrill and largely without value. See, for example, Jack Manno, *Arming the Heavens: The Hidden Military Agenda for Space, 1945–1995* (New York: Dodd, Mead, & Co., 1984); Loring Wirbel, *Star Wars: US Tools of Space Supremacy* (London: Pluto Press, 2004).

55. H. W. Brands, *The Devil We Knew: Americans and the Cold War* (New York: Oxford University Press, 1993).

56. David Lasser, *The Conquest of Space* (New York: The Penguin Press, 1931); Chas G. Philp, *Stratosphere and Rocket Flight (Astronautics)* (London: Sir Isaac Pitman & Sons, Ltd., 1935); P. E. Cleator, *Rockets Through Space: The Dawn of Interplanetary Travel* (New York: Simon & Schuster, 1936).

lar technologies worked, how they were developed, how they were tested, and finally, how they behaved during operational flights. De Witt Douglas Kilgore, in his recent *Astrofuturism: Science, Race, and Visions of Utopia in Space* (2003), calls the authors of this subgenre "scientists, engineers, and writers [who were] public apologists for the value of science."[57] Their works, grounded in scientific laws and mathematics, were not only accounts of past technological developments, but also contained narratives about the immense potential of engineers and managers to solve engineering problems; on a fundamental level, they are narratives about the "myth of [technological] progress."[58]

The programmatic histories typically encompass an arc from the conception of the project (the first chapter) to the final successful mission (the last) while maintaining a perspective that renders extraprogrammatic perspectives invisible. By rejecting contingency and context and embracing narratives of chronology and progress, they represent the distillation of teleology and Whiggish notions in space history.[59] The central actors in programmatic histories have typically been the artifact—the rocket engine, the launch vehicle, the spacecraft, and the ground complex. Such a focus reflects the organizational approach of the early American space program, where any new space technologies—such as liquid-hydrogen propulsion technology, for example—were developed under discrete NASA programs (in this case, Centaur).[60] As a result, programmatic histories have been frequently indistinguishable from artifactual histories.

Building on the tradition of Ley, Lasser, and others, beginning in the 1960s and continuing to the present, the NASA History Office has produced a series of works that have focused on particular programs. Although these studies were largely divorced from broader political, social, or cultural concerns, they served as important foundations for future historians to study how and why particular technologies emerged and how states and institutions arbitrate over questions of technology and management. An exemplary and excellent first step in the field was *The History of Rocket Technology: Essays on Research, Development, and Utility* (1964), a collection of essays on the development of ballistic missiles and spacecraft by a number of important architects

57. De Witt Douglas Kilgore, *Astrofuturism: Science, Race, and Visions of Utopia in Space* (Philadelphia: University of Pennsylvania Press, 2003).

58. For a critique of the "myth of progress" in the history of technology, see John Staudenmaier, *Technology's Storytellers: Reweaving the Human Fabric* (Cambridge, MA: MIT Press, 1985).

59. The term "Whig history" originally comes from Herbert Butterfield's *The Whig Interpretation of History* (London: G. Bell and Sons, 1931), where, in his examination of British constitutional history, he found a historical canon that framed history from a presentist stance without taking into account the viewpoints prevailing during the times of the figures under study. His was also an early critique of narratives centered on the "march of progress."

60. For Centaur, see Virginia P. Dawson and Mark D. Bowles, *Taming Liquid Hydrogen: The Centaur Upper Stage Rocket, 1958–2002* (Washington, DC: NASA SP-2004-4230, 2004).

of the U.S. rocketry and space program, including Walter R. Dornberger, Frank J. Malina, and Wernher von Braun. In his preface, then–NASA Chief Historian Eugene M. Emme argued that rocket technology was of fundamental importance to Western society, in effect restating the Cold War paradigm but linking it to the development of modern science and technology: "The eminence of Western science and technology—and all that this means, including but also beyond the connotations of national power—is not a little dependent upon the short and long-term success of technological progress in rocketry and astronautics."[61] All of these essays reflected prevailing interpretive trends in the relatively new field of history of technology, whose practitioners were fascinated with inventors, their inventions, and the effect of these inventions on society. In other words, these histories approached technology through deterministic and unidirectional perspectives where technology had profoundly impacted societies; the possibility of a reverse relationship was left unexplored. In his introduction to the 1964 volume, Emme encapsulated this view, suggesting that "rocketry has influenced the entire structure and conduct of national and international politics and economics."[62]

Since the Emme volume, NASA has sponsored numerous works in the canon, many of which have contributed to recording and chronicling important aspects of the country's efforts to explore space. The biggest subgroup—on human spaceflight—includes Swenson, Grimwood, and Alexander's *This New Ocean: A History of Project Mercury* (1966); Hacker and Grimwood's *On the Shoulders of Titans: A History of Project Gemini* (1977); Benson and Faherty's *Moonport: A History of Apollo Launch Facilities and Operations* (1978); Brooks, Grimwood, and Swenson's *Chariots for Apollo: A History of Manned Lunar Spacecraft* (1979); Compton and Benson's *Living and Working in Space: A History of Skylab* (1983); and Compton's *Where No Man Has Gone Before: A History of Apollo Lunar Exploration Missions* (1989).[63] Other NASA or NASA-sponsored books have focused on robotic missions, including NASA's extraordinarily successful and impressive deep space and interplanetary programs.[64] A recent work,

61. Eugene M. Emme, ed., *The History of Rocket Technology: Essays on Research, Development, and Utility* (Detroit: Wayne State University Press, 1964), p. 1.

62. Emme, *History of Rocket Technology*, p. 1.

63. Loyd S. Swenson, Jr., et al., *This New Ocean: A History of Project Mercury* (Washington, DC: NASA SP-4201, 1966); Barton C. Hacker and James C. Grimwood, *On the Shoulders of Titans: A History of Project Gemini* (Washington, DC: NASA SP-4203, 1977); Charles D. Benson and William Barnaby Faherty, *Moonport: A History of Apollo Launch Facilities and Operations* (Washington, DC: NASA SP-4204, 1978); Courtney G. Brooks et al., *Chariots for Apollo: A History of Manned Lunar Spacecraft* (Washington, DC: NASA SP-4205, 1979); W. David Compton and Charles D. Benson, *Living and Working in Space: A History of Skylab* (Washington, DC: NASA SP-4208, 1983); Compton, *Where No Man Has Gone Before*.

64. Richard Fimmel et al., *Pioneer Odyssey* (Washington, DC: NASA SP-394/396, 1977); Henry C. Dethloff and Ronald A. Schorn, *Voyager's Grand Tour: To The Outer Planets and Beyond* (Washington, DC: Smithsonian Institution Press, 2003).

No aspect of space travel is more exciting or has received greater historical attention than the human component. Too many observers, however, are too enthralled with the spectacle of flight to probe the history of the activity deeply. Here is the Return to Flight launch of Space Shuttle *Discovery* and its five-man crew from Pad 39B at 11:37 a.m., 29 September 1988, as *Discovery* embarked on a mission of 4 days and 1 hour. *(NASA image no. 88PC-1001)*

To Reach the High Frontier: The History of U.S. Launch Vehicles (2002), updated Emme's earlier seminal work by adding a number of essays on the technological development of the major American satellite launchers derived from Cold War–era warhorses such as the Atlas and Titan ICBMs.[65] The book was a timely update on the history of efforts to develop efficient access to space.

Beyond NASA, unofficial historians have devoted an enormous amount of ink and paper to the early American human spaceflight program. These works, which exploded in number in the late 1990s and the first decade of the 21st century, represent the perfectly idealized form of the programmatic and artifactual history. Many of the artifactual histories, such as Dennis Jenkins's

65. Roger D. Launius and Dennis R. Jenkins, eds., *To Reach the High Frontier: A History of U.S. Launch Vehicles* (Lexington: University Press of Kentucky, 2002). See also the essays on launch vehicles and access to space in John M. Logsdon et al., eds., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. 4, *Accessing Space* (Washington, DC: NASA SP-4407, 1999).

Space Shuttle: The History of the National Space Transportation System: The First 100 Missions (2001), comprise extremely thorough and informative narratives, providing an engineer's perspective on the many technical decisions during design, testing, and operations of particular projects.[66] Because of their distance from the original events, the prevailing context of a directionless American space program, and perceptions of American greatness compromised by liberals and social programs, these works communicate not only nostalgia, but also regret.[67] In *Leaving Earth* (2003), Robert Zimmerman notes, "Can we no longer imagine a future where humanity goes out and settles the far-flung stars? Have we become so small-minded that we cannot envision a tomorrow as idealistic and hopeful as that imagined by men like Ley, Korolev, and von Braun?"[68]

Histories of robotic exploration have been less mired in the betrayal of the post-Apollo times. Like their human spaceflight counterparts, they are coherent and useful accounts of humanity's first efforts to probe beyond circumterrestrial space. There exist comprehensive and technically detailed histories of Voyager, Galileo, Ulysses, and Mars Pathfinder, as well as broader histories of lunar and planetary exploration.[69] As part of its *Exploring the Unknown* series, NASA has also sponsored studies on scientific research by robotic probes.[70] The study of applications satellites (communications, weather, remote sensing, etc.) remains relatively neglected within the space history community, because it lacks the cachet of both human and deep space exploration, in part

66. Dennis R. Jenkins, *Space Shuttle: The History of the National Space Transportation System: The First 100 Missions* (Cape Canaveral, FL: D. R. Jenkins, 2001). See also Richard S. Lewis, *The Voyages of Columbia: The First True Spaceship* (New York: Columbia University Press, 1984).

67. See, for example, Robert Zimmerman, *Genesis: The Story of Apollo 8: The First Manned Flight to Another World* (New York: Four Walls Eight Windows, 1998); Harland, *Exploring the Moon*; John Catchpole, *Project Mercury: NASA's First Manned Space Programme* (London: Springer, 2001); David Shayler, *Gemini: Steps to the Moon* (London: Springer, 2001); David Shayler, *Skylab: America's Space Station* (London: Springer, 2001); David Shayler, *Apollo: The Lost and Forgotten Missions* (London: Springer, 2002); Reynolds, *Apollo*; Reginald Turnill, *The Moonlandings: An Eyewitness Account* (Cambridge, U.K.: Cambridge University Press, 2003).

68. Zimmerman, *Leaving Earth*, p. 463.

69. Henry S. F. Cooper, Jr., *Imaging Saturn: The Voyager Flights to Saturn* (New York: Holt, Rinehart, and Winston, 1982); Murray, *Journey into Space*; Burrows, *Exploring Space*; Robert Reeves, *The Superpower Space Race: An Explosive Rivalry Through the Solar System* (New York: Plenum Press, 1994); Donna Shirley and Danelle Morton, *Managing Martians* (New York: Broadway Books, 1998); Robert S. Kraemer, *Beyond the Moon: A Golden Age of Planetary Exploration, 1971–1978* (Washington, DC: Smithsonian Institution Press, 2000); David M. Harland, *Jupiter Odyssey: The Story of NASA's Galileo Mission* (London: Springer, 2000); Judith Reeves-Stevens et al., *Going to Mars: The Untold Story of Mars Pathfinder and NASA's Bold New Missions for the 21st Century* (New York: Pocket Books, 2000); David M. Harland, *Mission to Saturn: Cassini and the Huygens Probe* (London: Springer, 2002); Andrew Mishkin, *Sojourner: An Insider's View of the Pathfinder Mission* (New York: Berkeley Books, 2003); Paolo Ulivi, *Lunar Exploration: Human Pioneers and Robotic Surveyors* (London: Springer-Verlag, 2003); Ben Evans with David M. Harland, *NASA's Voyager Missions: Exploring the Outer Solar System and Beyond* (London: Springer, 2004).

70. Logsdon et al., *Exploring the Unknown*, vol. 5.

because these satellites carry no people and go nowhere. In contrast to human and deep space robotic spaceflight, the services offered by applications satellite systems deeply shape social, political, and cultural dimensions of societies. The objectives, capabilities, and design of such systems are in turn profoundly shaped by social, political, and cultural needs. Although many such "civilian" technological systems developed from firm connections with military projects, few historians have produced scholarship on their origins, performance, and ramifications.[71]

A number of historians and journalists have explored aspects of the many large-scale technological systems that were part of the American space program. These include management-focused histories such as Arnold S. Levine's *Managing NASA in the Apollo Era* (1982) and Stephen B. Johnson's *The Secret of Apollo: Systems Management in American and European Space Programs* (2002).[72] Two biographical works have enriched our understanding of the success of Apollo: Henry W. Lambright's *Powering Apollo: James E. Webb of NASA* (1995) and Robert C. Seamans's *Aiming at Targets: The Autobiography of Robert C. Seamans* (1996).[73] Both Webb and Seamans played critical roles in facilitating one of the most impressive and largest technological systems in 20th-century America. Their own words will be crucial for future historians interested in relocating Apollo in the same kind of social, political, and cultural context that Thomas P. Hughes did for electrical systems in his landmark *Networks of Power* (1983).[74]

T. A. Heppenheimer's multivolume history of the Space Shuttle is an important contribution to the programmatic space history genre. Although it

71. For the few works on applications projects, see Pamela E. Mack, *Viewing the Earth: The Social Construction of the Landsat System* (Cambridge, MA: MIT Press, 1990); David J. Whalen, *The Origins of Satellite Communications, 1945–1965* (Washington, DC: Smithsonian Institution Press, 2002); Donald H. Martin, *Communications Satellites*, 4th ed. (El Segundo, CA: Aerospace Press, 2000); Donna A. Demac, ed., *Tracing New Orbits: Cooperation and Competition in Global Satellite Development* (New York: Columbia University Press, 1986); P. Krishna Rao, *Evolution of the Weather Satellite Program in the U.S. Department of Commerce: A Brief Outline* (Washington, DC: NOAA, 2001); James M. Allen and Shanaka de Silva, "Landsat: An Integrated History," *Quest: The History of Spaceflight Quarterly* 12, no. 1 (2005): 6–22. See also the essays on satellite communications and remote sensing in John M. Logsdon et al., *Exploring the Unknown: Selected Documents in the History of the U.S. Civilian Space Program*, vol. 3, *Using Space* (Washington, DC: NASA SP-4407, 1998).

72. Arnold S. Levine, *Managing NASA in the Apollo Era* (Washington, DC: NASA SP-4102, 1982); Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore, MD: Johns Hopkins, 2002).

73. Henry W. Lambright, *Powering Apollo: James E. Webb of NASA* (Baltimore, MD: Johns Hopkins, 1995); Robert C. Seamans, *Aiming at Targets: The Autobiography of Robert C. Seamans* (Washington, DC: NASA SP-4106, 1996). See also the essays by Seamans, Webb, and other Apollo-era NASA managers, including Robert R. Gilruth, Wernher von Braun, George M. Low, Rocco A. Petrone, Samuel C. Phillips, and George E. Mueller, in *Apollo Expeditions to the Moon*, ed. Cortright.

74. Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore: Johns Hopkins, 1983).

skirts social issues and references no literature from the academic historiography of American technology, it represents a fleshed-out narrative that expertly describes the interplay between politics and technology that affected key milestones in the Shuttle program, including the requirements for such a system and how those requirements evolved over time depending on claims made by constituencies within NASA and the Department of Defense.[75] Similarly, Roger D. Launius's *Space Stations: Base Camps to the Stars* (2003) looks thematically at the historical development of space stations and their central role in the evolution of both prescriptive and practical plans for the exploration of space, entrenched partly by what Dwayne A. Day has called the dominant "von Braun" paradigm of space exploration.[76]

NOSE CONE HISTORY

The astronaut memoir (or, more broadly, the astronaut-centered history) constitutes one of the largest historical subgenres in the field of space history. I call these works "nose cone histories" since they describe a narrowly circumscribed circle of events visible only to the astronauts and in which only the astronauts were visible. For the millions who followed the space program in the 1960s, astronauts—not engineers nor servicepersons nor managers—were the most visible human representations of the technological accomplishments of the early Space Age. Our natural urge to distill all the meaning of the space program—in particular its avatar Apollo—was embodied potently by the astronauts. As Tom Wolfe described in *The Right Stuff* (1979), these young, able, athletic, and short-haired men each seemed an idealized version of an American everyman, with a wife, a picket fence, a shiny car—and yet simultaneously wrapped in myth and mystery.[77]

Some of the nose cone histories have added important dimensions of the story of the American human spaceflight program. For example, Apollo 11 astronaut Michael Collins, in his fascinating memoir *Carrying the Fire: As Astronaut's Journeys* (1974), shows a deep empathy and understanding of the role of astronauts in the halcyon days leading up to the epic Moon landing in 1969. Collins's narrative provided the first glimpse behind the iconogra-

75. T. A. Heppenheimer, *The Space Shuttle Decision: NASA's Search for a Reusable Space Vehicle* (Washington, DC: NASA SP-4221, 1999); Heppenheimer, *Development of the Space Shuttle, 1972–1981* (Washington, DC: Smithsonian Institution Press, 2002).

76. Launius, *Space Stations*. See also the equally fine Giovanni Caprara, *Living in Space: From Science Fiction to the International Space Station* (Willowdale, Ontario: Firefly Books, 2000). Less successful is Zimmerman's *Leaving Earth*, which is a sprawling and flawed attempt to locate the development of space stations in domestic and international politics. For the "von Braun paradigm," see Dwayne A. Day, "The Von Braun Paradigm," *Space Times* 33 (November–December 1994): 12–15.

77. Tom Wolfe, *The Right Stuff* (New York: Farrar, Straus and Giroux, 1979).

phy of the astronaut-as-unidimensional-hero of popular American culture, a self-sustaining myth given birth after the "original seven" Mercury astronauts were presented to the American media in 1959.[78] Collins described his colleagues as a complex group with diverse personality traits spanning the whole gamut: overachieving, academic, adventurous, risk-averse, emotionally distant, publicity-seeking, insecure, and brilliant. All were fully ready to do the job they were given. Further astronaut memoirs, particularly Walt Cunningham's *All-American Boys* (1977) and Gene Cernan's *The Last Man on the Moon* (1999), were, like Collins's pioneering work, candid about the singularly unique experiences of the NASA astronauts of the 1960s, especially their relationship to top management, their competitiveness among themselves, and their often complicated private lives.[79] Astronaut Donald "Deke" Slayton, the man responsible for selecting every American space crew between 1965 and 1975, added important historical details to how astronaut crews were picked—including Armstrong and Aldrin for the first lunar landing—in his posthumously published memoir, *Deke! An Autobiography* (1995).[80]

Fully fleshed, well-researched, and contextual biographies can say something profound not just about an individual, but also the period under study; yet most nose cone space histories have been narrow, hagiographic, or self-serving. They reinforce rather than explore the mythmaking associated with the astronaut as icon. They also continue to marginalize the many thousands who also worked on the space program; in other words, fetishization of the astronaut has been a potent barrier against a social history of the space program since, in the popular consciousness, the history of the American space program remains inseparable from the biographies and heroism of astronauts.[81]

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78. Michael Collins, *Carrying the Fire: An Astronaut's Journeys* (New York: Farrar, Straus and Giroux, 1974). Soon after their selection in 1959, the original seven astronauts signed deals with *Life* magazine for exclusive rights to bring their lives to the public. Apart from the many *Life* stories, one major output of this agreement was the very clinical book by W. Scott Carpenter et al., *We Seven, By the Astronauts Themselves* (New York: Simon & Schuster, 1962).

79. Walt Cunningham with Mickey Herskowitz, *The All-American Boys* (New York: Macmillan, 1977); Eugene A. Cernan and Donald A. Davis, *The Last Man on the Moon: Astronaut Eugene Cernan and America's Race in Space* (New York: St. Martin's Press, 1999).

80. Donald K. "Deke" Slayton and Michael Cassutt, *Deke! An Autobiography* (New York: St. Martin's Press, 1995). See also Joseph D. Atkinson, Jr., and Jay M. Shafritz's *The Real Stuff: A History of NASA's Astronaut Recruitment Program* (New York: Praeger, 1985) for a more academic perspective on astronaut selection.

81. Important exceptions to the bland astronaut-centered histories include two works by Henry S. F. Cooper: *Before Liftoff: The Making of a Space Shuttle Crew* (Baltimore: Johns Hopkins, 1987) and *A House in Space* (New York: Holt, Rinehart, and Winston, 1976). The former is an excellent study on the dynamics of forming and training crews for human spaceflight, while the latter explores the interactions of crew members on the long-duration *Skylab* missions. Jim Hansen's biography of Neil Armstrong, *First Man: The Life of Neil A. Armstrong* (New York: Simon & Schuster, forthcoming) also promises to be an important contribution to the field.

A new generation of space enthusiasts (affectionately called "space cadets" by some) has taken up the job of producing a slew of astronaut biographies. The first few published in the 1980s and 1990s provided unique viewpoints to the history of the American human space program, but by the early 2000s, their utility as history texts has diminished.[82] Many astronauts continue to write their own memoirs, usually ghost-written with others. The memoirs of some would suggest that travel through space engendered profound spiritual transformations—or often crises of the spirit—that led them to unexpected pathways.[83] The ones who achieved important management or advisory positions in the space program—such as Gemini and Apollo astronaut Thomas P. Stafford—have more to say than others. But all ponder, explore, and frequently advocate specific policies to give direction to a space program evidently lacking one since the golden age of Apollo.[84]

NEW HISTORY

In an article in 2000, then–NASA Chief Historian Roger D. Launius identified a "New Aerospace History" that emerged in the 1980s that was

82. See, for example, Colin Foale, *Waystation to the Stars: The Story of Mir, Michael, and Me* (London: Headline, 1999); Evelyn Husband with Donna Van Liere, *High Calling: The Courageous Life and Faith of Space Shuttle Commander Rick Husband* (Nashville, TN: Thomas Nelson, 2003); Colin Burgess et al., *Fallen Astronauts: Heroes Who Died Reaching the Moon* (Lincoln: University of Nebraska Press, 2003); Ray E. Boomhower, *Gus Grissom: The Lost Astronaut* (Indianapolis: Indiana Historical Society Press, 2004); Neal Thompson, *Light This Candle: The Life & Times of Alan Shepard—America's First Spaceman* (New York: Crown Publishers, 2004); Leon Wagener, *One Giant Leap: Neil Armstrong's Stellar American Journey* (New York: Forge, 2004); Nancy Conrad and Howie Klausner, *Rocketman: Astronaut Pete Conrad's Incredible Ride to the Moon and Beyond* (New York: New American Library, 2005).

83. Edwin E. Aldrin, Jr., with Wayne Warga, *Return to Earth* (New York: Random House, 1973); James Irwin and Williams Emerson Irwin, *To Rule the Night* (Philadelphia: A. J. Holman, 1973); Kathleen Maughn Lind, *Don Lind: Mormon Astronaut* (Salt Lake City: Deseret Book, 1985); Charlie Duke and Dotty Duke, *Moonwalker* (Nashville: Oliver-Nelson Books, 1990); Edgar D. Mitchell, *The Way of the Explorer: An Apollo Astronaut's Journey Through the Material and Mystical Worlds* (New York: G. P. Putnam's Sons, 1996); Gordon Cooper and Bruce Henderson, *Leap of Faith: An Astronaut's Journey into the Unknown* (New York: Harper Collins, 2000).

84. Armstrong et al., *First on the Moon*; Frank Borman with Robert J. Serling, *Countdown: An Autobiography* (New York: W. Morrow, 1988); Wally Schirra and Richard N. Billings, *Schirra's Space* (Boston: Quinlan Press, 1988); Jim Lovell and Kluger Jeffrey, *Lost Moon: The Perilous Voyage of Apollo 13* (Boston: Houghton Mifflin, 1994); Mike R. Mullane, *Liftoff! An Astronaut's Dream* (Parsippany, NJ: Silver Burdett Press, 1995); Bill Nelson with Jamie Buckingham, *Mission: An American Congressman's Voyage to Space* (San Diego: Harcourt Brace Jovanovich, 1988); Alan Bean with Andrew Chaikin, *Apollo: An Eyewitness Account by an Astronaut* (Shelton, CT: Greenwich Workshop Press, 1998); John Glenn and Nick Taylor, *John Glenn: A Memoir* (New York: Bantam Books, 1999); Jerry Linenger, *Off the Planet: Surviving Five Perilous Months Aboard the Space Station Mir* (New York: McGraw-Hill, 2000); Scott Carpenter, *For Spacious Skies: The Uncommon Journey of a Mercury Astronaut* (Orlando, FL: Harcourt, 2002); Thomas P. Stafford and Michael Cassutt, *We Have Capture: Tom Stafford and the Space Race* (Washington, DC: Smithsonian Institution Press, 2002).

"intrinsically committed to relating the subject to larger issues of society, politics, and culture and taking a more sophisticated view," a history that "move[d] beyond a fetish for the artifact."[85] More generally, Launius characterized these works as being in the middle ground between critique and celebration of the space program. I would modify Launius's typology by expanding the parameters to include a wider range of intellectual inquiry that often includes *both* critiques and celebration of the space program. They are, however, distinguished from the more traditional canon in two important ways: first, they do not rely on singular approaches to interpreting the history of space exploration, such as exploration, competition, technology, and astronauts. Instead, these works combine different elements of each and firmly locate their narratives in broader political, social, technological, and/or cultural contexts; i.e., they function as political, social, technological, and/or cultural histories. Second, they attempt to link to other historical subdisciplines such as the history of the Cold War, diplomatic history, and the history of science and technology.

In analyzing the new history, I describe important examples from each of four categories of new history—political, social, technological, and cultural history—and summarize opportunities for future research in each subgenre.

Political History

In the new history, political history has led the way in important reevaluations of the American space program. Walter A. McDougall's Pulitzer Prize–winning . . . *The Heavens and the Earth: A Political History of the Space Age* (1985) remains the most important and influential work in the genre. The book contributed to relocating the early years of the American space program in the broader context of postwar American politics. McDougall's main argument was that after World War II, and especially after Sputnik, the U.S. government marshaled resources on an unprecedented scale to promote advancements in science and technology, in effect, transforming the country into a new kind of 20th-century state, the technocracy. He noted:

> In those years [of the Sputnik challenge] the fundamental relationship between the government and new technology changed as never before in history. No longer did state and society react to new tools and methods, adjusting, regulating, or encouraging their spontaneous development. Rather, states took upon themselves the primary responsibility for generating new technology. This has meant that to the extent revolution-

85. Launius, "The Historical Dimension of Space Exploration," p. 23.

> ary technologies have profound second-order consequences in the domestic life of societies, by forcing new technologies, *all* governments have become revolutionary, whatever their reasons or ideological pretensions.[86]

In McDougall's formulation, the rise of a postwar technocracy was inseparable from the rise of the national security state, since federal policies on science and technology—especially after Sputnik—were closely related to countering the perceived intellectual and military power of the Soviet Union. McDougall's overarching thesis substantively redefined the way in which historians viewed the space program. If they had previously resorted to invoking the "natural" human urge to explore, technological fetishization, or international competition, his work redirected attention to a magnitude of changes on the domestic political and institutional stage associated with the origins of the space program.

McDougall also argued that the Eisenhower administration's concerns over establishing a "freedom of space" rationale guided its initial formulations of American space policy. According to McDougall, neither the White House nor the Department of Defense emphasized a policy of being first to launch an artificial satellite of the Earth; instead, national security considerations—such as establishing the "freedom of space" precedent, developing a military space program under the cover of a civilian one, and not diverting resources from the concurrent ICBM program—trumped any drive to beat the Soviets. McDougall's work challenged readers to reevaluate the ingrained notion of the Eisenhower administration's space policy as confused and ineffectual.[87] Besides facilitating a shift in the tone of historical scholarship on American space exploration, . . . *The Heavens and the Earth*'s Pulitzer Prize validated historical scholarship on the space program as worthy of serious academic study.

86. Walter A. McDougall, . . . *The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), pp. 6–7, emphasis in original.

87. Stephen E. Ambrose, in his multivolume biography of President Eisenhower, was the first to reframe the Eisenhower administration's role in the origins of the U.S. space program, but McDougall fully developed the idea. See Stephen E. Ambrose, *Eisenhower*, vol. 2, *The President* (New York: Simon & Schuster, 1983). The reevaluation of the Eisenhower administration's role in early U.S. space policy was fleshed out further in Rip Bulkeley, *The Sputniks Crisis and Early United States Policy: A Critique of the Historiography of Space* (Bloomington: Indiana University Press, 1991). For pathbreaking research on the "freedom of space" issue, see also Dwayne A. Day, "New Revelations about the American Satellite Programme Before Sputnik," *Spaceflight* 36 (1994): 372–373; R. Cargill Hall, "Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in *Exploring The Unknown: Selected Documents in the History of the U.S. Civil Space Program,* ed. John M. Logsdon et al., vol. 1, *Organizing for Exploration* (Washington, DC: NASA SP-4407, 1995), pp. 213–229; Dwayne A. Day, "Cover Stories and Hidden Agendas: Early American Space and National Security Policy," in *Reconsidering Sputnik: Forty Years Since the Soviet Satellite*, ed. Roger D. Launius et al. (Amsterdam: Harwood Academic Publishers, 2000), pp. 161–195.

Following in the footsteps of . . . *The Heavens and the Earth*, innovative scholarship by space policy scholar Howard E. McCurdy and historian Roger D. Launius advanced a reinterpretation of the "golden age" of Apollo at a 1993 symposium on presidential leadership and its influence on U.S. space policy. Instead of seeing Apollo as a "normal" stage in the evolution of American space policy, several historians argued that "the Apollo decision was . . . an anomaly in the history of the U.S. space program."[88] The implication was that policy-makers of the future could not use Apollo as a model of how to explore space since Apollo was intrinsically a unique product of its time that existed only because of exceptional circumstances, primarily national prestige and Cold War competition. Although this was not a new viewpoint, for the first time, space historians placed this notion as the key to understanding the early direction of American space exploration. In the conference proceedings, published as *Spaceflight and the Myth of Presidential Leadership* (1997), historians also argued that the role of presidential leadership in general may have been overestimated by advocates of space exploration after the Kennedy era. Recent reexaminations of Kennedy's historical 1961 decision to go to the Moon bolstered such a contrasting perspective.[89]

A 1997 conference on the 40th anniversary of Sputnik provided an opportunity for new and exciting scholarship on the origins and repercussions of the early American and Soviet space programs. Using recently declassified documents, historians amplified a number of important topics, including the "freedom of space" rationale for the beginning of the American space program, the selection of the Vanguard satellite project as the first civilian program, the formulation of the National Aeronautics and Space Act that led to the formation of NASA, and the effects of the National Defense Education Act that fundamentally altered the role of science and engineering in higher education in the United States. The collected papers from this conference, published as *Reconsidering Sputnik: Forty Years Since the Soviet Satellite* (2000), remain the most important set of intellectual inquiries into the origins of the American space program, complementing Robert Divine's systematic study of the Eisenhower administration's response to Sputnik, *The Sputnik*

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88. Roger D. Launius and Howard E. McCurdy, eds., *Spaceflight and the Myth of Presidential Leadership* (Urbana: University of Illinois Press, 1997), p. 9. See also W. D. Kay, *Can Democracies Fly in Space? The Challenge of Revitalizing the U.S. Space Program* (Westport, CT: Praeger, 1995).

89. See also James L. Kauffman, *Selling Outer Space: Kennedy, the Media, and Funding for Project Apollo, 1961–1963* (Tuscaloosa: University of Alabama Press, 1994); Michael R. Beschloss, "Kennedy and the Decision to Go to the Moon" in *Spaceflight and the Myth of Presidential Leadership*, pp. 51–67; Stephen J. Garber, "Multiple Means to an End: A Reexamination of President Kennedy's Decision to Go to the Moon," *Quest: The History of Spaceflight Quarterly* 7, no. 2 (1999): 5–17; Andrew Chaikin, "White House Tapes Shed Light on JFK Space Race Legend," *Space.com*, 22 August 2001, *http://www.space.com/news/kennedy_tapes_010822.html*; Roger D. Launius, "Kennedy's Space Policy Reconsidered: A Post-Cold War Perspective," *Air Power History* 50, no. 4 (2003): 16–29.

Challenge (1993).[90] Similar reevaluations have been focused on other presidential administrations and their positions on initiatives within the civilian space program.[91]

The new political history suggests six broad areas ripe for future scholarship. These include the following:

1) Revisiting the early American space program in light of the complex debates within the canon of Cold War history, including studies of the space program as an adjunct for the less savory dimensions of American foreign policy; additionally, historians could explore not only how the Cold War shaped the contours of the civilian and military space programs, but also how the latter shaped aspects of the former; Giles Alston's dissertation on the influence of Apollo on international relations points to further avenues of research.[92]

2) Further study of the ways in which different administrations have used specific initiatives and programs as part of political agendas unrelated to the stated goals of the initiatives or programs;[93] surprisingly, there exist no systematic studies of the Nixon or Reagan administration's stance towards civilian and military space policy.

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90. Launius et al., *Reconsidering Sputnik*; Robert A. Divine, *The Sputnik Challenge: Eisenhower's Response to the Soviet Satellite* (New York: Oxford University Press, 1993); Lafayette P. Temple III, "Organizing Space: The Political-Bureaucratic Dynamics Through 1961" (Ph.D. diss., George Washington University, 1999). See also Matt Bille and Erika Lishock, *The First Space Race: Launching the World's First Satellites* (College Station: Texas A&M University, 2004), which assembled all the new research into a single volume; Roger D. Launius, "Eisenhower, Sputnik, and the Creation of NASA: Technological Elites and Public Policy Agenda," *Prologue* 28 (summer 1996): 127–143; Peter J. Roman, *Eisenhower and the Missile Gap* (Ithaca, NY: Cornell University Press, 1995).

91. McCurdy, *The Space Station Decision*; Mark Damohn, *Back Down to Earth*; Krug, *Presidential Perspectives on Space Exploration*; Thor Nels Hogan, "Mars Wars: A Case History of Agenda Setting and Alternative Generation in the American Space Program" (Ph.D. diss., Public Policy and Public Administration Department, George Washington University, 2004). In addition, Launius and McCurdy's *Spaceflight and the Myth of Presidential Leadership* includes a number of important essays on Eisenhower, Kennedy, Johnson, Reagan, and George H. W. Bush.

92. Giles Alston, "International Prestige and the American Space Programme" (Ph.D. diss., Queen's University of Belfast, 1989).

93. For some examples, see Dwayne A. Day, "Space Policy-Making in the White House: The Early Years of the National Aeronautics and Space Council," in *Organizing for the Use of Space*, ed. Launius, pp. 117–154; Joan Hoff, "The Presidency, Congress, and the Deceleration of the U.S. Space Program in the 1970s," and Robert H. Ferrell, "Presidential Leadership and International Aspects of the Space Program," both in *Spaceflight and the Myth of Presidential Leadership*, ed. Launius and McCurdy, pp. 92–132 and 172–204, respectively. For a comparative study of NASA under two different administrations, see John D. Kelley, "An Organizational History of the National Aeronautics and Space Administration: A Critical Comparison of Administrative Decision Making in Two Pivotal Eras" (Ph.D. diss., University of Southern California, 2002).

3) The relationship, exchanges, and competition between the civilian and military/intelligence space programs, in terms of intelligence, hardware, and managerial and engineering expertise;[94] for example, how does the movement of high administrators (such as Dan Goldin and Michael Griffin) from one sector affect NASA policies?

4) The connections between foreign policy and domestic space policy, a vast topic which has been studied piecemeal, but not in any systematic and long *durée* approach.

5) The relationship between domestic political transactions (congressional politics, redistricting, lobbying, policy papers, advisory boards, etc.) and the making of space policy.

6) The role of institutions in the making of civilian and military space policy; the scholarship would encompass the study of why certain institutions are created, others are dissolved, what kind of inertia they carry through their history, and the ways in which particular institutions relate to others.

History of Technology

The second broad field of new history has emerged from within the bounds of the history of technology. Most artifactual histories of space programs tend to accept implicitly notions of technological determinism, especially that the space program exists as autonomous technology, affecting society around it but not being affected by it. There have been many works on the societal impacts of space exploration;[95] the field of space exploration has, however, largely been insulated from the paradigmatic revolution in the history of

94. For general perspectives, see Dwayne A. Day, "Invitation to Struggle: The History of Civilian-Military Relations in Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, ed. John M. Logsdon, vol. 2, *External Relations* (Washington, DC: NASA SP-4407, 1996), pp. 233–270; Mark A. Erickson, "The Evolution of the NASA-DoD Relationship from Sputnik to the Lunar Landing" (Ph.D. diss., George Washington University, 1997). For exchanges of hardware between "black" and civilian space projects, see Dwayne A. Day's "Not So Black and White: the Military and the Hubble Space Telescope," *Space Times* 34 (March–April 1995): 20–21, and "From Above the Iron Curtain to Around the Moon," *Spaceflight* 47 (2005): 66–71. For an excellent work on the relationships between private industry, government-funded intelligence satellite programs, and technological innovation, see Jonathan E. Lewis, *Spy Capitalism: Itek and the CIA* (New Haven, CT: Yale University Press, 2002).

95. See, for example, Lillian A. Levy, ed., *Space, Its Impact on Man and Society* (New York: Norton, 1965); Raymond A. Bauer et al., *Second-Order Consequences: A Methodological Essay on the Impact of Technology* (Cambridge, MA: MIT Press, 1969); Charles P. Boyle, *Space Among Us: Some Effects of Space Research on Society* (Washington, DC: AIAA, 1974); Tim Greve et al., eds., *The Impact of Space Science on Mankind* (New York: Plenum Press, 1976).

technology in the 1980s that redirected focus from technological determinism to the social construction of technology (and technological systems).[96] A few notable exceptions include Pamela E. Mack's *Viewing the Earth: The Social Construction of the Landsat System* (1990) and Donald A. Mackenzie's *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (1990).[97] In the latter, Mackenzie argued that missile accuracy was not an inevitable consequence of technical change, but rather part of a process involving negotiation between a wide range of actors. His use of missile guidance as a window into exploring how accuracy was socially constructed suggests important future avenues of further research on the space program, including studies of the ways in which crew safety, mission success, or risk assessments in the human space program have been negotiated and socially constructed.

The social constructivist approach is to some degree related to the influential shift in the literature on technological systems. In moving the study of the history of technology from artifacts to systems, historian Thomas P. Hughes's work fundamentally altered the ways in which historians conceived of the relationship between technology and society.[98] Tentative steps towards a view of space projects as large-scale technological systems were taken in important works such as R. Cargill Hall's *Lunar Impact: A History of Project Ranger* (1977) and Roger E. Bilstein's *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles* (1980).[99] Similarly, Charles Murray and Catherine Bly Cox's excellent *Apollo: The Race to the Moon* (1989) describes the Apollo project as a system whose primary actors were managers, engineers, politicians, and organizations rather than astronauts. Based on documentation and interviews with the remaining living actors of the endeavor, their reconstruction of the Apollo project as a milestone in the history of management makes it probably the single best historical overview of Apollo.[100]

Beyond social constructivism, others have begun the work of looking at the space program as a case study in technological culture. In *Goals in Space:*

96. For seminal early works on the social construction of technology, see Wiebe J. Bijker et al., eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: MIT Press, 1987); Wiebe J. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, MA: MIT Press, 1995); Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, MA: MIT Press, 1994).

97. Mack, *Viewing the Earth*; Donald A. Mackenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, MA: MIT Press, 1990).

98. Hughes, *Networks of Power*; Thomas P. Hughes, *Rescuing Prometheus* (New York: Pantheon Books, 1998).

99. R. Cargill Hall, *Lunar Impact: A History of Project Ranger* (Washington, DC: NASA SP-4210, 1977); Roger E. Bilstein, *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles* (Washington, DC: NASA SP-4206, 1980).

100. Charles Murray and Catherine Bly Cox, *Apollo: Race to the Moon* (New York: Simon & Schuster, 1989).

American Values and the Future of Technology (1991), William Sims Bainbridge used sociological methods to investigate how actors in American culture have used language in popular discussions on space exploration. On the institutional and organizational side, Diane Vaughan, in *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (1996), used interdisciplinary approaches derived from sociology and communications theory to analyze the culture of NASA in the 1980s.[101] Her research illustrates the ways in which organizations develop their own culture that, depending on the scarcity of resources, fosters an environment that finds high risk acceptable without breaking any major rules. Her conception of the "normalization of deviance" suggests important avenues of further research, especially for studying space projects that did not achieve any significant successes.[102]

Others have explored more esoteric approaches to the technological history of the space program. In *The Religion of Technology* (1997), David F. Noble investigates the role of scripture and definable Christian symbolism in the "dreaming" for space exploration in the pre-Sputnik days and the invocation of God as a transcendental element in the rhetoric of modern-day managers, activists, and astronauts.[103] If not all of his ruminations are convincing, his findings on the prehistory of space travel suggest as-yet-unexplored opportunities for scholarship on the relationship between religion and spaceflight in the early 20th century, furthered recently by Roger D. Launius in a meditation on utopianism and space advocacy.[104] David E. Nye, in his essay "Don't Fly Me to the Moon: The Public and the Apollo Space Program," also contributes to the move away from technological determinism. He challenges the near-sacred notions among the "space cadet" community that the history of space exploration was of any significance in the history of humanity; he also questions the notion that "experiencing outer space transformed inner consciousness," a claim which hinged on the images of a fragile Earth as seen from deep space by the Apollo astronauts. He concludes that retrospect has made Apollo a unifying memory when in reality, during its execution, the polity and populace remained fractured over its symbolic and material benefits. He concludes, "Just as all Americans revere their Revolution, even though less than half the population actively supported it in 1776, the Apollo Program appears to be gaining sanctity in retrospect."[105]

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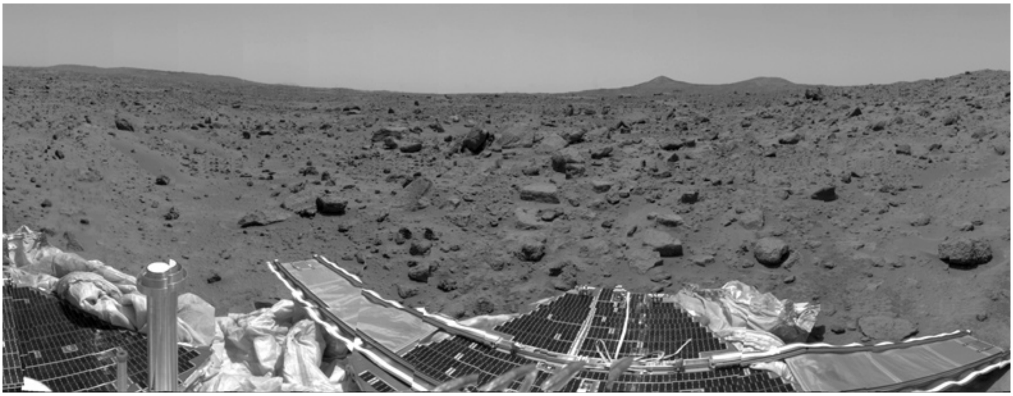
101. Diane Vaughan, *Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1996).

102. Vaughan's analysis, of course, also influenced the work of the Columbia Accident Investigation Board.

103. David F. Noble, *The Religion of Technology: The Divinity of Man and the Spirit of Invention* (New York: Alfred A. Knopf, 1997), pp. 115–142.

104. Launius, "Perfect Worlds, Perfect Societies."

105. David E. Nye, *Narratives and Spaces: Technology and the Construction of American Culture* (New York: Columbia University Press, 1997), p. 160.



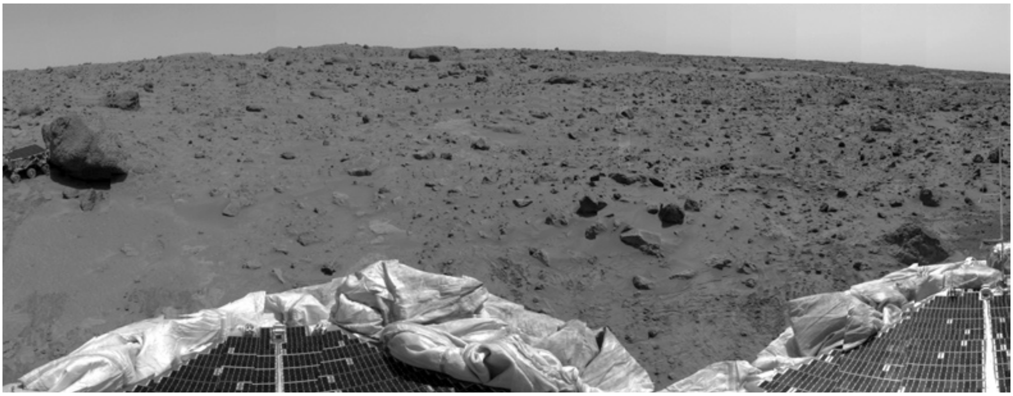
Robotic spaceflight has yielded significant new understandings about the solar system. This is the first contiguous, uniform, 360-degree color panorama taken by the Imager for Mars Pathfinder (IMP) over the course of sols 8, 9, and 10 (Martian days) in 1997. Different regions were imaged at different times over the three Martian days

These new works underscore that, collectively, historians need to move beyond methodological approaches that embrace technological determinism, Whiggish history, and program-centered histories. They suggest six areas for further research:

1) Despite nearly 40 years of writing space history, we still do not have a substantive history of space technology, work focused not on programs but on the technologies that constitute a complete system capable of spaceflight, including rocket engines, solar cells, fuel cells, communications equipment, thermal protection, guidance systems, materials, etc.[106] We need histories that are neither programmatic nor artifact-centered; for example, a history of satellite-based optical systems (cameras, lenses, mirrors, data recovery, etc.) could shed light on the relationship between a particular technology, commercial industry, or the military and the way in which consumers can shape technologies.

2) An important but unexplored aspect of the space industry is the economic history of space manufacturing—in particular of rockets, engines, and satellites, which would illuminate issues of government-industry relations, quality control, and labor practices; it is also

106. For works on discrete technologies, see Lillian D. Kozloski, *U.S. Space Gear: Outfitting the Astronaut* (Washington, DC: Smithsonian Institution Press, 1993); Eldon C. Hall, *Journey to the Moon: The History of the Apollo Guidance Computer* (Reston, VA: AIAA, 1996); Gary L. Harris, *The Origins and Technology of the Advanced Extravehicular Space Suit* (San Diego, CA: Univelt, 2001); James A. Dewar, *To the End of the Solar System: The Story of the Nuclear Rocket* (Lexington: University of Kentucky Press, 2004).



to acquire consistent lighting and shadow conditions for all areas of the panorama. At left is a lander petal and a metallic mast that is a portion of the low-gain antenna. Deflated air bags are visible at the perimeters of all three lander petals. *(NASA image no. PIA00752)*

necessary to locate this history within the broader history of mass production in America.[107]

3) Journalists have devoted much attention to the various disasters of the Space Age, but besides one significant exception—David Shayler's *Disasters in Manned Spaceflight* (2000)—they have been focused narrowly on particular incidents.[108] Because the literature on space history has had a triumphalist arc (introduction, plot thickens, crisis, triumph over adversity), it has ignored accounts of long-range technological failures, which can also shed light on abandoned lineages of technologies and the contingencies that shaped our adoption of certain systems over others.[109]

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107. For mass production in general, see David A. Hounshell's seminal *From the American System to Mass Production* (Baltimore: Johns Hopkins, 1984). For a brief essay on the economics of the space program, see Henry R. Hertzfeld, "Space as an Investment in Economic Growth," in *Exploring the Unknown,* ed. Logsdon, vol. 3, pp. 385–400.

108. David Shayler, *Disasters and Accidents in Manned Spaceflight* (New York: Springer, 2000). For various disaster-focused works, see Henry S. F. Cooper, *Thirteen, the Flight That Failed* (New York: Dial Press, 1972); Malcolm McConnell, *Challenger: A Major Malfunction* (Garden City, NY: Doubleday, 1987); Joseph Trento, *Prescription for Disaster* (New York: Crown, 1987); Richard S. Lewis, *Challenger: The Final Voyage* (New York: Columbia University Press, 1988); Claus Jensen and Barbara Haveland, *No Downlink: A Dramatic Narrative about the Challenger Accident and Our Time* (New York: Farrar, Straus and Giroux, 1996); Michael Cabbage and William Harwood, *Comm Check: The Final Flight of Shuttle Columbia* (New York: Free Press, 2004).

109. For technological failure, see Neil Schlager, ed., *When Technology Fails: Significant Technological Disasters, Accidents and Failures of the Twentieth Century* (Detroit: Gale Research, 1994); Azriel Lorber, *Misguided Weapons: Technological Failure and Surprise on the Battlefield* (Washington, DC: Brasseys, 2002).

4) The social constructivist approach remains a powerful methodological tool for in-depth studies of any number of rocket and spaceflight systems, including, for example, the Space Shuttle, which is an excellent case for studying how different actors can shape the form and function of a technological system; such an approach would help to avoid the deterministic historical narratives that assume, for example, that the liquid-propellant rocket was the obvious method to reach space without questioning the social and cultural forces that led Tsiolkovskiy, Goddard, Oberth, and others to arrive at the rocket as the propulsive force for access to space.

5) A relatively unexplored area is the social construction of risk in space technological systems; for example, we know little in a systematic way about the manner in which risk has been constructed, defined, and invoked in human versus robotic systems, in different human spaceflight programs, among engineers and flight directors, etc. An important unexplored question remains the historical evolution of what it means to "man-rate" a vehicle.

6) We still do not have well-researched histories on the continuing tension between robotic and human spaceflight; specific areas of inquiry could include the interplay between technology, policy, and organizational culture in determining choices for robotic versus human spaceflight; what role economics plays in these choices; and the ways in which we measure "output" for given space projects (whether human or robotic) and how these evaluations may or may not be contingent upon premiums placed upon human or robotic spaceflight. Finally, a useful avenue of research may be to explore why and how, during the early space era (especially in the pre-Sputnik years), policy-makers overwhelmingly emphasized human spaceflight in their public advocacy.

Social History

Beyond political history, several historians and sociologists have taken up the job of moving beyond nose cone history into broader social themes. An early progenitor of this subgenre was William S. Bainbridge's *The Spaceflight Revolution: A Sociological Study* (1976). Although his focus was primarily on spaceflight visionaries from the late 19th and early 20th centuries, Bainbridge argued that the advancement of technology was not necessarily deterministic. In fact, in cases of revolutionary technology such as the rocket, the principal actors (such as von Braun) maneuvered the government and military into facilitating resources to implement their goals of spaceflight. Thus, instead of being co-opted by the state, scientists and engineers opportunistically took advantage of the state.[110]

Historians have also investigated a number of methodological issues related to the study of the early space program, including the problem of doing contemporary or near-contemporary history. Because of the recent nature of the history of space exploration, participants can play a large role in the way space history is chronicled. Participants provide evidence for historians, write history books, and sometimes dismiss nonparticipant history with a "you-weren't-there" rationale; historians respond by condescending to the participants by invoking "that noble dream" of objectivity and distance.[111] Space historians must explicitly address these methodological concerns if their goal is to produce history without baggage.

Beyond methodological concerns, an important aspect of the social dimension of spaceflight has been the relationship between public opinion and the space program. Mark E. Byrnes, in his *Politics and Space: Image Making by NASA* (1994), traced the effects of NASA's image-building policy on popular perceptions of the organization as well as broader support for the cause of space travel. He argued that NASA primarily used three images—nationalism, romanticism, and pragmatism—to create and consolidate political support across the nation for its major endeavors in space.[112] Similar work by others has helped to challenge many accepted notions about public advocacy for the space program. Using quantitative data, for example, Herbert E. Krugman found that "given the extensive media coverage of the space events throughout [the Apollo program], favorable publicity did not seem to have generated equally favorable public support for the Apollo program."[113] Roger D. Launius found that popular support for the space program remained at the same relative level both during and after the Apollo program, undercutting the received notion

110. William S. Bainbridge, *The Spaceflight Revolution: A Sociological Study* (New York: Wiley, 1976).

111. For a history of the search for objectivity in the discipline of history in American academia, see Peter Novick's *That Noble Dream: The 'Objectivity Question' and the American Historical Profession* (Cambridge, U.K.: Cambridge University Press, 1988). For some of the methodological considerations in writing space history, see Joseph N. Tatarewicz, "Writing the History of Space Science and Technology: Multiple Audiences with Divergent Goals and Standards," in *The Historiography of Contemporary Science and Technology*, ed. Thomas Söderqvist (Amsterdam: Harwood Academic Publishers, 1997), pp. 71–89.

112. Mark E. Byrnes, *Politics and Space: Image Making by NASA* (Westport, CT: Praeger, 1994). See also James L. Kauffman, *Selling Outer Space: Kennedy, the Media, and Funding for Project Apollo, 1961–1963* (Tuscaloosa: University of Alabama Press, 1994); Lynn Marie Disbrow, "A Metaphorical Analysis of the Evolution of NASA's Public Image, 1962–1986" (Ph.D. diss., Wayne State University, 1989).

113. Herbert E. Krugman, "Public Attitudes Toward the Apollo Space Program, 1965–1975," *Journal of Communication* 27, no. 4 (1977): 87–93.

of a "golden age" of mass support for the space program.[114] Expanding the frontier on social histories of the Space Age, recent studies have also focused on hitherto unexplored but crucial elements of the history of spaceflight such as the pro-space movement, the impact of the space program on geographical locales, and engineers as a mass demographic.[115]

Beyond these important exceptions, social history, which revolutionized mainstream American history beginning in the 1960s, has not made many inroads into space history. I identify five areas for further study concerning the relationship between society and space:

1) The history of the space program remains incomplete unless we explore the lived experiences and backgrounds of large demographic groups such as engineers, servicemen and -women, military and intelligence personnel involved in programs, launch personnel, staff workers, spouses and families of engineers in both the civilian and military space programs, etc.

2) Further exploration is necessary on the relationship between public advocacy and political commitment in the context of the space program, extending the work already done; such approaches would require explorations of the efficacy of formal and informal lobby groups.

3) In the past few years, a number of historians have taken steps into exploring the place of gender in the history of the space program; all of the work so far has focused on early women contenders for the astronaut corps, the so-called FLATs (First Lady Astronaut Trainees); most of these are narrow "surgical" histories that say little beyond recounting their life histories. The one exception, Margaret Weitekamp's superb *Right Stuff, Wrong Sex: America's First Women in Space Program* (2004), uses the FLATs story to revisit the social and cultural codes that guided broader American views on women, technology, and exploration in late-20th-century America.[116] Yet these

114. Roger D. Launius, "Public opinion polls and perceptions of US human spaceflight," *Space Policy* 19 (2003): 163–175.

115. Michael A. G. Michaud, *Reaching for the High Frontier: The American Pro-Space Movement, 1972–84* (New York: Praeger, 1986); William Barnaby Faherty, *Florida's Space Coast: The Impact of NASA on the Sunshine State* (Gainesville: University Press of Florida, 2002); Sylvia D. Fries, *NASA Engineers and the Age of Apollo* (Washington, DC: NASA SP-4104, 1992).

116. Margaret A. Weitekamp, *Right Stuff, Wrong Sex: America's First Women in Space Program* (Baltimore: Johns Hopkins, 2004). See also Bernice Trimble Steadman with Jody M. Clark, *Tethered Mercury: A Pilot's Memoir: The Right Stuff—but the Wrong Sex* (Traverse City, MI: Aviation

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works still leave much to be done since we still do not have any systematic studies of the role of women in much larger demographics who participated in the space program—in engineering, medicine, administration, and staff positions, as well as the thousands who were spouses in a predominantly male-dominated project;[117] we also need histories of women astronauts who actually flew in space, as opposed to those who never did.

4) We need more studies of how the growth of the space industry has affected particular geographical locales, particularly Texas, Alabama, California, and Florida; space historians need to rise up to the challenge to link subdisciplines such as urban history to space history by chronicling, for example, the transformation of urban sites through development and abandonment cycles or the motivations of many young scientists and engineers to pursue a career in the space program.[118]

5) The American space program was most identified with a White male demographic which reflects the natural distribution of those who managed and participated in the endeavor, yet it is important that we have a good understanding of the role and place of the space program demographic through broader—and, in some ways, cataclysmic—changes in the social fabric of American society from the 1960s to the 1990s in terms of racial relations and immigration.[119]

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Press, 2001); Pamela Freni, *Space for Women: A History of Women with the Right Stuff* (Santa Ana, CA: Seven Locks Press, 2002); Stephanie Nolen, *Promised the Moon: The Untold Story of the First Women in Space Race* (New York: Four Walls Eight Windows, 2003); Bettyann Kevles, *Almost Heaven: The Story of Women in Space* (New York: Basic Books, 2003); Martha Ackmann, *The Mercury 13: The Untold Story of 13 American Women and the Dream of Spaceflight* (New York: Random House, 2003).

117. For recent autobiographical works that touch on broader issues of the role of women engineers in the American space program, see Shirley and Morton, *Managing Martians*; M. G. Lord, *Astro Turf: The Private Life of Rocket Science* (New York: Walker & Co., 2004). See also the piece on women who worked at Australia's Woomera Rocket Range: Kerrie Dougherty, "Calculating Women: A Brief History of the LRWE/WRE Computing Team," *Quest: The History of Spaceflight Quarterly* 9, no. 4 (2002): 31–39.

118. A recent pathbreaking article on the influence of postwar suburbanization on physicists' selection of professional topics is exemplary of the kinds of new work in other fields. See David Kaiser, "The Postwar Suburbanization of American Physics," *American Studies* 56, no. 4 (2004): 851–888.

119. Like the gender issue, the role of race in the American space program has been explored only through the focus of astronauts. See for example, J. Alfred Phelps, *They Had A Dream: The Story of African-American Astronauts* (Novato, CA: Presidio, 1994); Stanley P. Jones, *African-American Astronauts* (Mankato, MN: Capstone High/Low Books, 1998); Mae Jemison, *Find Where the Wind Goes: Moments From My Life* (New York: Scholastic, 2001); Betty Kaplan Gubert et al., *Distinguished African Americans in Aviation and Space Science* (Westport, CT: Oryx Press, 2002). There is also a large canon of juvenile literature on African American astronauts.

Cultural History

The cultural history of spaceflight is the most recent subgenre in the field and also the most heterogeneous. A survey of the key works shows deep and broad work encompassing everything from relatively orthodox studies of the place of spaceflight in American culture to more postmodern meditations on modernity, masculinity, and machines. Perhaps the earliest work in the field was Norman Mailer's *Of a Fire on the Moon* (1969), which, coming as it did in the year of Apollo 11, contrasted sharply with other contemporary accounts of Apollo.[120] Using field research, Mailer constructed a narrative that illustrated the clash—and sometimes rapprochement—between the young counterculture of the late 1960s and the pseudomilitary culture of NASA. Mailer implicitly critiqued what he believed was the militarized and regimented culture of NASA, with its middle-class values that cherished patriotism and encouraged unquestioned adherence to the dominant political culture.

A few authors have explored how the space program has resonated in modern literature. In the insightful *Seeing Earth: Literary Responses to Space Exploration* (1985), Ronald Weber deconstructed many of the attendant metaphors that cultural commentators—writers, poets, scholars, philosophers, theologians, astronauts, and others—have used to invoke, explain, extol, and critique the American space program, locating their meditations between the broad themes of "liberating leap into a mysterious future" and a new appreciation of the Earth itself.[121] William D. Atwill, in *Fire and Power: The American Space Program as Postmodern Narrative* (1994), adopts a similar methodological approach but takes a more critical stance towards the American space program, specifically Apollo. His thought-provoking explorations, which touch on domestic shocks of the Vietnam War, try to unpack "the difficulty so many writers had telling [the] story of a technocratic enterprise simultaneously central and antithetical to the time and place that produced it."[122]

Dale A. Carter also referenced American literature—in his case, Thomas Pynchon's classic novel *Gravity's Rainbow* (1973)—but had a more ambi-

120. Norman Mailer, *Of a Fire on the Moon* (New York: New American Library, 1969). See also W. David Lewis, "Buzz Aldrin's Return to Earth: The Astronaut and Social Values in Apollo Era America," *Quest: The History of Spaceflight Quarterly* 6, no. 1 (1998): 40–43.

121. Ronald Weber, *Seeing Earth: Literary Responses to Space Exploration* (Athens: Ohio University Press, 1985). For other, similar explorations, see Laurence Goldstein, *The Flying Machine and Modern Literature* (Bloomington: Indiana University Press, 1986); George Held, "Men on the Moon: American Novelists Explore Lunar Space," *Michigan Quarterly Review* 18 (spring 1979): 318–342; Laurence Goldstein, "'The End of All Our Exploring': The Moon Landing and Modern Poetry," *Michigan Quarterly Review* 18 (spring 1979): 192–217. For a look at space and the visual medium, see Laura M. Andre, "Lunar Nation: The Moon and American Visual Culture, 1957–1972" (Ph.D. diss., University of North Carolina, 2002).

122. William D. Atwill, *Fire and Power: The American Space Program as Postmodern Narrative* (Athens, GA: University of Georgia Press, 1994), p. 11.

tious goal: to rewrite the postwar history of the American space program as a critique of American expansionist military and economic aims. In Carter's worldview, the American space program represented a "Rocket State," a confluence of civilian and military interests with little or no moral code. The book remains one of the most important synthetic cultural histories of the American space program.[123] Other, similar critiques of the American space program have emerged from the new cultural history and include David Lavery's *Late for the Sky: The Mentality of the Space Age* (1992), which rejects one of the most fundamental assumptions of space mythology, taken as gospel by other cultural commentators such as Wyn Wachhorst, that humans are propelled by unknown and innate forces to explore space.[124]

New work has also focused on popular culture. While not strictly a cultural history, Howard E. McCurdy's *Space and the American Imagination* (1997) remains one of the most powerful studies on how popular conceptions of space exploration in American culture helped to shape national space policy.[125] The iconography of space exploration in the 1950s, McCurdy argued, tapped deeply into some of America's most entrenched cultural ideals such as the "limitless frontier," the "heroic explorer," the romance of aviation through Lindbergh and Earhart, and ultimately the utopian ideal of progress through technology.[126] Space enthusiasts and advocates such as Wernher von Braun used many of the same cultural representations in their lobbying but added the fear of the Soviet threat during the Cold War. By invoking the specter of world domination in the late 1950s and early 1960s, they were able to influence major policy decisions, including Kennedy's historic decision to go to the Moon in 1961.[127] Marina Benjamin's eloquent *Rocket Dreams: How the Space Age Shaped Our View and the Future of Technology* (2003) is the view from the other side, i.e., how the space program has affected popular culture. Her exploration of how popular culture has relegated the "space age" to a cultural

123. Dale Carter, *The Final Frontier: The Rise and Fall of the American Rocket State* (London: Verso, 1988).

124. David Lavery, *Late for the Sky: The Mentality of the Space Age* (Carbondale: Southern Illinois University Press, 1992); Wyn Wachhorst, *The Dream of Spaceflight: Essays on the Near Edge of Infinity* (New York: Basic Books, 2000).

125. Howard E. McCurdy, *Space and the American Imagination* (Washington, DC: Smithsonian Institution Press, 1997).

126. See also James A. Spiller, "Constructing America at the Peripheries: The Cultural Politics of United States Science and Exploration in Outer Space and Antarctica, 1950s–1990s" (Ph.D. diss., University of Wisconsin, 1999); Susan L. Mangus, "Conestoga Wagons to the Moon: The Frontier, the American Space Program, and National Identity" (Ph.D. diss., Ohio State University, 1999).

127. See also Mike Wright, "The Disney–Von Braun Collaboration and Its Influence on Space Exploration," in *Inner Space/Outer Space: Humanities, Technology and the Post-Modern World*, ed. Daniel Schenker, Craig Hanks, and Susan Kray (Huntsville, AL: Southern Humanities Press, 1993), pp. 151–160.

hinterland in the post-Apollo era is a powerful investigation into why the "space age" resonated in the first place to so many.[128]

Along with the works of McCurdy and Benjamin, De Witt Douglas Kilgore's *Astrofuturism* (2003) represents one of the three most important books on the cultural history of spaceflight to appear thus far.[129] Marshaling an impressive array of source material, Kilgore investigates the conflicting ideals embedded in America's vision of the future as represented in intellectual, scientific, artistic, and political discourse of the late 20th century. The power of Kilgore's work lies not only in his explication of how and why a whole progress-oriented and futuristic space discourse resonated with so many in American culture, but also why Americans have found certain values in knowledge, politics, and art so desirable. The work depicts the history of futures propagated, struggled over, and, in some cases, lost.[130]

These recent works point to six different areas within the cultural history of spaceflight fertile for future scholarship:

1) The role of memory, myth, and nostalgia in shaping current understanding of the history of spaceflight remains unexplored; deconstructing the Apollo myth in popular discourse—particularly its resale as cultural cachet via what Michael L. Smith has called "commodity scientism"—may deepen our understanding of why Apollo retains such a grip on the collective memory.[131]

2) Going beyond hagiographical treatments of astronauts, cultural historians should devote attention to the complex role astronauts play as part of the iconography of heroism in American culture; further exploring the groundwork laid by Tom Wolfe in his seminal *The Right Stuff* (1979) as well as focusing on astronauts in the post-Apollo era

128. Marina Benjamin, *Rocket Dreams: How the Space Age Shaped Our Vision of a World Beyond* (New York: Free Press, 2003). See also Paul Levinson, *Realspace: The Fate of Physical Presence in the Digital Age, On and Off the Planet* (London: Routledge, 2003), a similar meditation on the ways in which the digital age may have dampened humanity's urge to explore space.

129. Kilgore, *Astrofuturism*. See also his "Engineers' Dreams: Wernher von Braun, Willy Ley, and Astrofuturism in the 1950s," *Canadian Review of American Studies* 27, no. 2 (1997): 103–131.

130. See also Roger D. Launius, "Perceptions of Apollo: Myth, Nostalgia, Memory, or All of the Above?" *Space Policy* 21 (May 2005): 129–139; Roger D. Launius and Howard E. McCurdy, *Imagining Space: Achievements, Predictions, Possibilities, 1950–2050* (San Francisco: Chronicle Books, 2001); Bruce Horrigan, "Popular Culture and Visions of the Future in Space, 1901–2001," in *New Perspectives on Technology and American Culture*, ed. Bruce Sinclair (Philadelphia: American Philosophical Society, 1986), pp. 49–67.

131. Michael L. Smith, "Selling the Moon: The U.S. Manned Space Program and the Triumph of Commodity Scientism," in *The Culture of Consumption: Critical Essays in American History, 1880–1980*, ed. Richard Wrightman Fox and T. J. Jackson Lears (New York: Pantheon Books, 1983), pp. 175–209.

would add significantly to understanding the shaping and evolution of the astronaut icon from hero and explorer in the 1960s to mechanic and experimenter in the 21st century.[132] Susan Faludi's *Stiffed: The Betrayal of the American Man* (1999), where she argues that the emasculation of the astronaut in the post-Apollo era in part contributed the "betrayal" of the "American Man," suggests that the fall of the astronaut icon was as salient as its rise, but the extant scholarship remains woefully incomplete.[133]

3) A cultural history of the Space Age would be incomplete without fully researched scholarship on the rituals that have shaped the lives of not only participants in the space program but also those who witnessed it as viewers;[134] similarly, we need to revisit the history of space travel through the lens of popular scientific culture.[135] An area ripe for investigation is the ways in which popular space culture shaped the lives of adolescents in the 1960s through science fiction, popular magazines, toys, models, and clubs.[136]

4) The recent graphic anthology *2001: Building For Space Travel* (2001) was an important step in connecting space culture with the history of the built environment on Earth, particularly architecture;[137] there still remains much to be done in terms of connecting the history of space exploration with the history of material culture—automobiles, toys, home appliances—to name only a few examples.

5) Essential for studying the history of space exploration is the role of particular ideologies—whether utopian, spiritual, millenarian, excep-

132. Wolfe, *The Right Stuff.*

133. Susan Faludi, *Stiffed: The Betrayal of the American Man* (New York: William Morrow & Co., 1999). See also Debra Benita Shaw, "Bodies Out of this World: The Space Suit as Cultural Icon," *Science as Culture* 13 (March 2004): 123–144.

134. For early explorations on this field, see several articles by Colin Fries in *Quest: The History of Spaceflight Quarterly*: "Space Age Legends: Urban Folk Tales Collected by the NASA Headquarters History Office" (vol. 8, no. 1 [2000]: 18–23), "Flying for Us: Space Age Milestones Celebrated in Music" (vol. 9, no. 3 [2002]: 30–36), "Sports Milestones in Space" (vol. 10, no. 2 [2003]: 37–40), and "Traditions of the Space Age" (vol. 11, no. 1 [2004]: 31–39).

135. For a notable exception, which primarily covers the media of TV and film, see Robert A. Jones, "They Came in Peace for all Mankind: Popular Culture as a Reflection of Public Attitudes to Space," *Space Policy* 20 (2004): 45–48.

136. For a brief look at the relationship between the proliferation of science fiction and the cause of spaceflight in the U.S., see the essay "Rockets to the Moon, 1919–1944: A Debate Between Reality and Fiction," in Paul A. Carter, *Politics, Religion, and Rockets: Essays in Twentieth Century American History* (Tucson: The University of Arizona Press, 1991), pp. 181–195.

137. John Zukowsky, ed., *2001: Building for Space Travel* (New York: Harry N. Abrams, 2001).

tionalist, modernist, humanist, atheistic, technological, environmental, or other—that motivated advocates, critics, and participants (direct and vicarious) of spaceflight in the 20th century.[138]

6) A few have begun to revisit the history of space exploration through the theoretical framework of feminist studies, some through a reading of such sources as female-written "slasher" novels. Constance Penley's *NASA/TREK: Popular Science and Sex in America* (1997) critically tackles, among many topics, the role of sexuality in spaceflight culture and also discusses NASA's "inability to manage the meanings of women in space";[139] additionally, Yaakov Jerome Garb's ecofeminist approach to reevaluating the famous photograph of the whole Earth from lunar distance focused not on the epiphany of (re)discovering "one world" for all of humanity, but rather on how that iconic image of the Earth helped to entrench a more negative view, one of the dispassionate gaze of omniscient science as a masculine epistemology controlling all of nature, knowledge, and humanity.[140] Finally, in *Cosmodolphins: Feminist Cultural Studies of Technology, Animals and the Sacred* (2000), authors Mette Bryld and Nina Lykke used a critical feminist approach to unpack the relationships between the Space Age, the "New Age," and the ecological symbolism of nature (represented through the icon of the dolphin). In taking a feminist approach to rewriting the master narratives of spaceflight, they identified what I believe is an important topic for future historians, the relationship between national identity and the making of history. They write:

> The early space race was, amongst other things, a discursive battle over entitlement to represent Universal Man in the biggest story told in modern times. Who was going to be the script writer and the protagonist of the master narrative of mankind's cosmic exodus? This was and is a

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138. For an unusual look at space culture through "posthuman theory," see Melanie A. R. Brown, "Posthumanity's Manifest Destiny: NASA, Its Contradictory Image and Promises, and Popular Culture" (Ph.D. diss., University of Central Florida, 2004).

139. Constance Penley, *NASA/TREK: Popular Science and Sex in America* (New York: Verso, 1997), p. 3.

140. Yaakov Jerome Garb, "The Use and Misuse of the Whole Earth Image," *Whole Earth Review* no. 45 (March 1985): 18–25, and "Perspective or Escape? Ecofeminist Musings on Contemporary Earth Imagery," in *Reweaving the World: The Emergence of Ecofeminism*, ed. Irene Diamond and Gloria Feman Orenstein (San Francisco: Sierra Club Books, 1990), pp. 264–278. See also Jonathan Bordo, "Ecological Peril, Modern Technology and the (Post)Modern Sublime," in *Shadow of Spirit: Postmodernism and Religion*, eds. Phillipa Berry and Andrew Wernick (New York: Routledge, 1992), pp. 165–178.

> question that matters a great deal when the official story of spaceflight is retold [separately in the U.S. and Russia].[141]

Their conclusions hint at further opportunities for research on national claims for the history of space travel: which was more "important" in the history of space exploration, the first time a human left the planet Earth (Yuri Gagarin) or the first time a human set foot on another celestial body (Neil Armstrong)? Ask a Russian and then an American, and one would get different responses. In both cases, historians use extraordinary metaphors to imbue them with gravity, comparisons that typically center on the movement of Earthly life from the oceans to land. The parallel narratives are contradictory but exist simultaneously in multiple national discourses, buttressed by masculine notions of rationalism, exploration, and evolution. In some sense, space historians need to question how "thematic consensus" in space historiography was shaped by national identity.

Conclusions

The flavor of American space history has also been profoundly shaped by the location and sponsorship of its primary practitioners. In other words, American *space* history largely remains "court history." For the past 40 years, it has been predominantly sponsored, written, and issued as a result of funding from sources who direct and operate the space program, i.e., the U.S. government (through NASA, the Smithsonian's National Air and Space Museum, and the Department of Defense) or major corporations. Because there has been no vibrant nongovernmental or noncorporate space history community (in academia, public history positions, or elsewhere), American space history has been much more conservative than other historical subdisciplines. The field has typically had a romance with the power and progress inherent in technology; it eulogizes and deifies a few important men; and it eschews any position that would criticize celebratory, jingoistic, or militaristic elements of the space program. The works of those who have broken this mold despite their connections to official organizations—Launius, Logsdon, McCurdy, and Neufeld, for example—collectively represent an important and positive, albeit minority, trend in the field of space history.[142]

141. Mette Marle Bryld and Nina Lykke, *Cosmodolphins: Feminist Cultural Studies of Technology, Animals and the Sacred* (London: Zed Books, 2000).

142. Michael J. Neufeld's work, particularly his seminal *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (Cambridge, MA: Harvard University Press, 1995), revolutionized the history of the wartime German ballistic missile program by providing a balanced treatment of the development of the V-2 that did not gloss over the terrible human costs of its development.

The mainstream academic community has devoted very little attention to the space program, partly because academics tend to be narrowly focused on topics such as race, ethnicity, and gender. Typically, academics have had a condescending attitude towards fields such as the history of technology or space history, partly because they see in these fields little of interest to such contemporary conceptual lenses such as poststructuralism; postcolonial studies; feminist studies; and issues revolving around gender, ethnicity, power, transnationalism, and sexuality. Academics have often refused to see the complexities of the space program, relying instead on unidimensional, weak, and often lazy interpretations of the space program as a bankrupt and militaristic element of American society.

The publication of syntheses can say much about a particular discipline. On the one hand, in a field that is very young, one might expect most works to be somewhat of a synthesis given the paucity of subject matter. On the other hand, maturity and longevity of a discipline and its attendant accumulation of source material might also engender the writing of syntheses. Since the beginnings of the field of space history, journalists and historians have tackled the problem of the synthesis with various degrees of success. Von Braun and Ordway's *History of Rocketry and Space Travel* (1966) was an early attempt that emphasized some of the key motifs of Cold War historiography such as exploration, competition, and the social welfare of all humankind. The work focused on great figures, civilian space exploration, and the potential benefits of the project.[143] More comprehensive works appeared in the 1980s and 1990s that benefited from post–Cold War revelations. T. A. Heppenheimer's *Countdown: A History of Spaceflight* (1997) traced the evolution of rocketry from pioneering theoreticians in the late 19th century to the mid-1990s. Heppenheimer's marshaling of information is masterful, and his use of inspiring language complements his view that Apollo was "a drive toward a new human future."[144] Tom Crouch's *Aiming for the Stars: The Dreamers and Doers of the Space Age* (1999) is an eloquent exegesis on innovators in the 20th century who tried to translate their visions of space exploration—both successfully and unsuccessfully—into reality.[145] Although focused on great men and great technology, Heppenheimer's and Crouch's works remain the most successful syntheses in the traditional style of space history.[146]

143. Von Braun and Ordway, *History of Rocketry and Space Travel.* The monograph was published in several updated versions up to 1985.

144. T. A. Heppenheimer, *Countdown: A History of Spaceflight* (New York: John Wiley & Sons, 1997), p. 2.

145. Tom D. Crouch, *Aiming for the Stars: The Dreamers and Doers of the Space Age* (Washington, DC: Smithsonian Institution Press, 1999).

146. For other syntheses, see Andrew Wilson, *The Eagle Has Wings: The Story of American Space Exploration, 1945–1975* (London: British Interplanetary Society, 1982); David Baker, *The History*

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Other recent syntheses remain flawed by their dated interpretations. William E. Burrows, in his *This New Ocean: The Story of the First Space Age* (1998), used an array of recently declassified material from both the United States and former Soviet Union to produce an otherwise eloquent narrative of the entire Space Age.[147] Burrows's work, however, derives solidly from the Cold War framework of space exploration as a battle of noble proportions against a morally untrustable adversary. In demonizing communism as "more insidious" than Nazism, he describes the former as a "cancer, a disease that surreptitiously rode the bloodstream of the world, attacking and devouring every healthy organism in its path and growing bigger and more dangerous as it did so."[148] By dismissing all of Soviet society as cancerous yet eulogizing such men as Sergei Korolev, such works inevitably end up in contradictions since we are left with no insight into how the former managed to produce the likes of the latter. Similarly, Mike Gruntman, in *Blazing the Trail: The Early History of Spacecraft and Rocketr*y (2004), provides a well-researched and comprehensive tale of the history of rocketry and spaceflight, with lucid explanations of technologies, but does Burrows one better by repeatedly denigrating not only the Russians but also American and Western liberals who questioned the American space program.[149]

With the rise of the new history, two threads of historiography now exist. One remains celebratory and internalist and the other questioning and externalist. Although there has been spillover from the former to the latter, the reverse, as evident in the works of Burrows and Gruntman, has been less common. It is clear, though, that both traditions have very important contributions to make. The old internalist history, focused on important men and singular artifacts, provided the backbone of our conception of the history of the space program. The new externalist history contributes the rationale, explication—and the critiques—that make the old history meaningful. Despite the large canon of space history, those who have written syntheses have not man-

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of Manned Spaceflight, 2nd ed. (New York: Crown Publishers, 1985); Michael Collins, *Liftoff: The Story of America's Adventure in Space* (New York: Grove Press, 1988); H. P. Arnold, ed., *Man in Space: An Illustrated History of Spaceflight* (New York: Smithmark, 1993); Roger D. Launius, *NASA: A History of the U.S. Civil Space Program* (Malabar, FL: Krieger Publishing Company, 1994); Helen Gavaghan, *Something New Under the Sun: Satellites and the Beginning of the Space Age* (New York: Copernicus, 1998).

147. William E. Burrows, *This New Ocean: The Story of the First Space Age* (New York: Random House, 1998).

148. Ibid., p. 148.

149. In describing the development of the Woomera missile test range in Australia in the 1960s, for example, Gruntman notes that "pacifists and communists tried to interfere with the construction, as their counterparts invariably did with defense initiatives in other countries of the free world, thus serving willingly or unwittingly as a Soviet fifth column" (Mike Gruntman, *Blazing the Trail: The Early History of Spacecraft and Rocketry* [Reston, VA: AIAA, 2004], p. 425).

aged to combine the two in any coherent fashion. One way to engender such a union would be for historians of spaceflight to engage much more actively with the mainstream American history community.[150] Unlike the literature on American history, the writing on American space history is very young, but by engaging with a bigger audience—not only the broader public but also the academic history community—we might benefit from a rich vista of viewpoints that would move us forward from a fledgling subdiscipline to one that is vibrant, mature, and complex. And with maturity, we might yet see a powerful work that brings together the dictates of policy, the forces of society, and the nuances of culture into a grand narrative that chronicles the romance and the reality of this country's efforts to explore space.

150. It is of some importance that in the "list of upcoming meetings" section of the past four issues of *News & Notes*—the regular newsletter issued to the aerospace history community by the NASA History Office—one would find announcements for the many meetings of professional aerospace organizations but none for the annual meetings of the American Historical Association (AHA) or the Organization of American Historians (OAH). See the last four newsletters: NASA History Office, *News & Notes* 21, nos. 1–4 (2004).

Chapter 15

The History and Historiography of National Security Space[1]

Stephen B. Johnson

The intent of this essay is to provide space historians with an overview of the issues and sources of national security space so as to identify those areas that have been underserved. Frequently, ballistic missiles are left out of space history, as they only pass through space instead of remaining in space like satellites. I include ballistic missiles for several reasons, not the least of which is that they pass through space en route to their targets.

Space programs originated in the national security (NS) arena, and except for a roughly 15-year period from the early 1960s through the mid-1970s, NS space expenditures in the United States (U.S.), let alone the Union of Soviet Socialist Republics (USSR), have equaled or exceeded those of civilian programs. Despite this reality, the public nature of government-dominated civilian programs and issues of security classifications have kept NS space out of the limelight. The recent declassification of the early history of the National Reconnaissance Office (NRO) and the demise of the Soviet Union have led to a recent spate of publications that have uncovered much of the "secret history" of the early Cold War. Nonetheless, much of NS space history has received little attention from historians.

One feature of military organizations that is of great value for historians is their penchant to document their histories, and space organizations are no exception. Most military organizations have historians assigned to them, with professional historians at many of the positions documenting events as they occur.

Unfortunately, this very positive feature is countered by the requirements of secrecy and classification (and, in the case of the Naval Research Laboratory, the loss of its archives by fire). It is unfortunately true that much of this treasure trove of documentation created by historians within space organizations will remain classified for years to come. Some of the earlier

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1. Many thanks to David Arnold, Donald Baucom, Matt Bille, Dwayne Day, Steve Dick, R. Cargill Hall, and Rick Sturdevant, all of whom provided many useful comments and provided me with many more sources than I would ever have been able to find on my own.

material is being declassified now or could be declassified if someone would request it and if sufficient priority were assigned to the task. This is a field where outsiders can be of great service.

To exploit the mass of documents that exist requires that historians have a basic grasp of the subject, what has been published to date, and what is yet to be done. This article aims to perform these functions by surveying the various military space programs and issues, giving a very brief sketch of their histories, and identifying the main sources that historians have created and used.

OVERVIEW SOURCES

While there is no single comprehensive overview history of NS space, several works cover a variety of areas. Walter McDougall's Pulitzer Prize–winning . . . *The Heavens and the Earth*, written in 1985, thoroughly discussed the NS aspects of the space race; it is getting dated but remains useful for an introduction to the politics of the 1950s and 1960s.[2] William Burrows's *This New Ocean* integrates NS space issues nicely into his acclaimed overview space history.[3] Mike Gruntman's *Blazing the Trail* is an overview history of space technology, accounting for military contributions.[4] So, too, does Asif Siddiqi's authoritative *Challenge to Apollo* for the Soviet program up to the mid-1970s, which also has a fine essay on Soviet space history sources.[5] Peter Hays[6] and Dwayne Day[7] provide overviews of military and intelligence space, respectively, in Eligar Sadeh's *Space Politics and Policy*.

An earlier, short review of the state of national security space research is provided by Day's 1997 article, which focuses on issues as opposed to a bibliographic treatment.[8] Day provided an overview of U.S. military space

2. Walter McDougall, . . . *The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985).

3. William E. Burrows, *This New Ocean: The Story of the First Space Age* (New York: The Modern Library, 1998).

4. Mike Gruntman, *Blazing the Trail: The Early History of Spacecraft and Rocketry* (Reston, VA: American Institute of Aeronautics and Astronautics, 2004).

5. Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974* (Washington, DC: NASA SP-2000-4408, 2000).

6. Peter L. Hays, "Space and the Military," in *Space Politics and Policy, an Evolutionary Perspective*, ed. Eligar Sadeh (Dordrecht, Netherlands: Kluwer Academic Publishers, 2002), pp. 335–370.

7. Dwayne A. Day, "Intelligence Space Program," in *Space Politics and Policy, an Evolutionary Perspective*, ed. Sadeh, pp. 371–388.

8. Dwayne A. Day, "The State of Historical Research on Military Space," *Journal of the British Interplanetary Society* 50 (1997): 203–206. See also Roger D. Launius, "The Military in Space: Policy-Making and Operations in a New Environment," in *A Guide to the Sources of United States Military History: Supplement IV*, ed. Robin Higham and Donald J. Mrozek (North Haven, CT: Archon Books, 1998), pp. 488–522.

operations from 1987 to 1995 in *Journal of the British Interplanetary Society* in December 1993, as well as an updated and extended version of the article in *Countdown*.[9] Cargill Hall and Jacob Neufeld wrote an early work that gives a flavor of USAF activities.[10] David Spires's overview history of the USAF in space is the best single place to start for the USAF portion of NS space history.[11] Curtis Peebles's *High Frontier* is a much shorter introduction to USAF space history.[12] USAF Space Command recently published a two-volume set of basic documents that are of great value to military space historians.[13]

Steven Zaloga's *The Kremlin's Nuclear Sword* is the best overview of Soviet control of and defense against nuclear forces.[14] Nicholas Daniloff's 1972 *The Kremlin and the Cosmos* is an early but important source on the Soviet program,[15] as is Christian Lardier's *L'Astronautique Soviétique*,[16] which is excellent for the technical aspects of Soviet space systems. Gerald Borrowman wrote a short overview of Soviet military space activities in 1982.[17] Nicholas Johnson created yearly assessments of the Soviet space program, some of which are summarized in *Soviet Space Programs, 1980–1985*.[18] His 1987 *Soviet Military Strategy in Space* was also a major work at the time.[19] Finally, Johnson's books *Europe and Asia in Space: 1993–1994* and *Europe and Asia in Space: 1991–1992* are outstanding sources for those two regions.[20]

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9. Dwayne A. Day, "A Review of Recent American Space Operations," *Journal of the British Interplanetary Society* 46, no. 12 (1993): 459–470; Dwayne A. Day, "Capturing the High Ground: The U.S. Military in Space, 1987–1995, Part 1," *Countdown* 13, no. 1 (1995): 30–45; Dwayne A. Day, "Capturing the High Ground: The U.S. Military in Space, 1987–1995, Part 2," *Countdown* 13, no. 3 (1995): 17–31.

10. R. Cargill Hall and Jacob Neufeld, *The U.S. Air Force in Space: 1945 to the 21st Century* (Washington, DC: USAF History and Museums Program, 1998).

11. David N. Spires, *Beyond Horizons: A Half Century of Air Force Space Leadership* (Peterson AFB, CO: Air Force Space Command, 1997).

12. Curtis Peebles, *High Frontier: The United States Air Force and the Military Space Program* (Washington, DC: Air Force History and Museums Program, 1997).

13. David N. Spires, *Orbital Futures: Selected Documents in Air Force Space History*, vol. 1 (Peterson AFB, CO: Air Force Space Command, 2004); David N. Spires, *Orbital Futures: Selected Documents in Air Force Space History*, vol. 2 (Peterson AFB, CO: Air Force Space Command, 2004).

14. Steven J. Zaloga, *The Kremlin's Nuclear Sword: The Rise and Fall of Russia's Strategic Nuclear Forces, 1945–2000* (Washington, DC: Smithsonian Institution Press, 2002).

15. Nicholas Daniloff, *The Kremlin and the Cosmos* (New York: Alfred A. Knopf, 1972).

16. Christian Lardier, *L'Astronautique Soviétique* (Paris: Armand Colin, 1992).

17. Gerald L. Borrowman, "Soviet Military Activities in Space," *Journal of the British Interplanetary Society* 35, no. 2 (1982): 86–92.

18. Nicholas L. Johnson, *Soviet Space Programs, 1980–1985* (San Diego: Univelt Press, 1987).

19. Nicholas L. Johnson, *Soviet Military Strategy in Space* (Coulsdon, U.K.: Jane's Information Group, 1987).

20. Nicholas L. Johnson, *Europe and Asia in Space: 1993–1994* (Kirtland AFB, NM: USAF Phillips Laboratory, 1995; Colorado Springs, CO: Kaman Sciences Corporation, 1995); Nicholas L. Johnson, *Europe and Asia in Space: 1991–1992* (Kirtland AFB, NM: USAF Phillips Laboratory, 1993; Colorado Springs, CO: Kaman Sciences Corporation, 1993).

Some encyclopedic sources are useful. The latest *Cambridge Encyclopedia of Space* has significant information about military space, particularly in providing summaries of all programs and launches up to 2000.[21] Shirley Thomas's eight-volume *Men of Space* from the 1960s remains a useful source.[22] The forthcoming space history encyclopedia *Space Exploration and Humanity* will have a major section on NS space history.[23]

Samuel Miller's *An Aerospace Bibliography* is a good starting point to search for space history articles prior to 1978,[24] as is John Looney's 1979 bibliography for NASA.[25] So, too, is the Smithsonian bibliography edited by Dominic Pisano and Cathleen Lewis, *Air and Space History: An Annotated Bibliography*, which takes researchers up to 1988.[26] Jeffrey Richelson edited *Military Uses of Space, 1946–1991*, a useful bibliographic source.[27]

With the explosion of the World Wide Web in the 1990s, no discussion of sources can avoid online sources. An excellent online source for aerospace history, including defense space matters, is the government site for the U.S. Centennial of Flight Commission. This contains a plethora of short essays on a variety of aerospace history topics.[28] The NASA History Division also has an excellent site with many online publications, including many that involve NASA-DOD relations. The Air War College Gateway is another excellent resource of past and current military space activities.[29] Other credible sites include those for USAF Space Command, the National Security Archives of George Washington University, and the Federation of American Scientists. Several declassified USAF works are now online.[30] Mark Wade's online

21. Fernand Verger, Isabelle Sourbès-Verger, and Raymond Ghirardi, with contributions by Xavier Pasco, *The Cambridge Encyclopedia of Space* (Cambridge: Cambridge University Press, 2003).

22. Shirley Thomas, *Men of Space: Profiles of the Leaders in Space Research, Development, and Exploration*, 8 vols. (Philadelphia: Chilton Company, 1960–68).

23. Stephen B. Johnson et al., eds., *Space Exploration and Humanity: A Historical Encyclopedia* (Santa Barbara, CA: ABC-CLIO, forthcoming, expected publication 2006–07).

24. Samuel Duncan Miller, *An Aerospace Bibliography* (Washington, DC: Office of Air Force History, USAF, 1986).

25. John J. Looney, *Bibliography of Space Books and Articles from Non-Aerospace Journals, 1957–1977* (Washington, DC: NASA History Office, 1979).

26. Dominick A. Pisano and Cathleen S. Lewis, eds., *Air and Space History: An Annotated Bibliography* (New York: Garland Publishing, 1988).

27. Jeffrey Richelson, ed., *U.S. Military Uses of Space, 1945–1991: Index and Guide* (Washington, DC: The National Security Archive; Alexandria, VA: Chadwyck-Healey, Inc., 1991).

28. United States government, Centennial of Flight Web site, *http://www.centennialofflight.gov*.

29. Air War College Gateway to Space Operations and Resources, *http://www.au.af.mil/au/awc/awcgate/awc-spc.htm*.

30. Mark C. Cleary, *The 6555th: Missile and Space Launches through 1970* (Patrick AFB, FL: 45th Space Wing, 1991); Mark C. Cleary, *The Cape: Military Space Operations, 1971–1992* (Patrick AFB, FL: 45th Space Wing, 1994); Harry Waldron, *Historical Overview of the Space and Missile Systems Center, 1954–2003* (Los Angeles AFB, CA: Space and Missile Systems Center, 2003).

Encyclopedia Astronautica has become a popular Internet source for space history. Unfortunately, while it contains a great deal of information, not all of it is correct. Space historians have noticed a variety of factual problems, and unfortunately these problems have not been consistently repaired. Since this is not a peer-reviewed source and historical errors have not always been fixed, this cannot be considered a reliable source, despite its impressive appearance. Many other online sources have the same problems.[31]

Since reactions to the launch of Sputnik encompassed a variety of areas and actions, it is appropriate to mention a few key sources about that event and its ramifications here. The best recent overview is Roger Launius, John Logsdon, and Robert Smith's *Reconsidering Sputnik*.[32] Important earlier works on the topic include those by Robert Divine[33] and Rip Bulkeley.[34]

BALLISTIC MISSILES AND MILITARY SPACE LAUNCHERS

Ballistic missiles originated from the rocketry experiments of amateurs in the 1920s and 1930s, which then gained the interest of military organizations, particularly in Germany, the Soviet Union, and the United States. These stories have been described in a variety of books and articles through the years, as they account for the origins of space programs around the world.

The story of the German V-2 project is perhaps the best known, both because it led to the world's first operational ballistic missile and because of its leader, Wernher von Braun, who became famous in the United States after World War II. American forces captured most of von Braun's team at the end of World War II, along with parts and plans to rebuild the Nazi program on American soil. Most of the team came to the United States, where they assisted American contractors and the U.S. military to develop their own ballistic missile capabilities. The United States already had its own rocketry programs, with the Navy working with physicist Robert Goddard and members of the American Rocket Society, and the Army funding the Jet Propulsion Laboratory. Missile efforts proliferated after the war but did not gain priority until the early 1950s. Only then did the Air Force's Atlas ICBM project, soon followed by the Thor, Titan, and other ballistic missile programs, push forward at a rapid pace. These liquid-propellant rockets were soon displaced as weapons by solid-propellant

31. *Encyclopedia Astronautica* is available online at *http://www.astronautix.com/*.

32. Roger D. Launius, John M. Logsdon, and Robert W. Smith, eds., *Reconsidering Sputnik: Forty Years Since the Soviet Satellite* (Amsterdam: Harwood Academic Publishers, 2000).

33. Robert A. Divine, *The Sputnik Challenge: Eisenhower's Response to the Soviet Satellite* (Oxford: Oxford University Press, 1993).

34. Rip Bulkeley, *The Sputniks Crisis and Early United States Space Policy* (Bloomington: Indiana University Press, 1991).

ballistic missiles such as Minuteman and Polaris, which were much more useful militarily because they did not require a time-consuming and dangerous liquid fueling process. Once the Cold War ended, ballistic missile forces in the United States shrank rapidly along with the Soviet threat. Other nations each developed their own nuclear and ballistic missile programs.

Ballistic missiles were the technical progenitors of the first-generation space launchers. The Atlas, Titan, and Thor missiles led to the Atlas, Titan, and Delta families of launchers, while the R7 became the Soyuz launcher. Similarly, early Chinese ballistic missile programs derived from the Nazi V-2 through the Soviet R1 and R2 programs evolved into the Long March series used for military and civilian launches.

Finally, the military also developed hypersonic technologies from the 1950s to the present, some of which evolved into craft capable of going into space. The X-series aircraft went faster and higher, culminating in the X-15 and X-20 Dyna-Soar programs of the early 1960s. Later efforts included the X-24, involvement with the Space Shuttle program, and the National Aerospace Plane, and they continue today with a variety of studies and tests.

The early history of ballistic missile programs in Germany, the United States, and the Soviet Union is well documented. Nazi efforts on the V-2 program are the subject of many books with a variety of perspectives. The single best volume on the V-2 development program is Michael Neufeld's *The Rocket and the Reich*,[35] thoroughly researched from the German-language original documents. Overview space histories, such as Burrows's *This New Ocean* and Heppenheimer's *Countdown*, also provide good descriptions of the V-2 project, as well as both Soviet and American ballistic missile programs through the 1950s.[36] Older histories stemmed mainly from von Braun supporters, such as Frederick Ordway's *The Rocket Team* and Walter Dornberger's *V-2: The Nazi Rocket Weapon*.[37] Less well known is the actual V-2 rocket campaign against Britain and British countermeasures, well documented in King and Kutta's *Impact: The History of Germany's V-Weapons in World War II*.[38] R. V. Jones's *The Wizard War* gives an earlier description of British espionage efforts in World War II, including against the V-2 offensive.[39] Revisionist histories

35. Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (New York: The Free Press, 1995).

36. Burrows, *This New Ocean*; T. A. Heppenheimer, *Countdown: A History of Space Flight* (New York: John Wiley & Sons, 1997).

37. Walter Dornberger, *V-2: The Nazi Rocket Weapon,* trans. James Cleugh and Geoffrey Halliday (New York: Viking, 1954); Frederick I. Ordway III and M. Sharpe, *The Rocket Team: From the V-2 to the Saturn Moon Rocket* (New York: Thomas Y. Crowell, 1979).

38. Benjamin King and Timothy Kutta, *Impact: The History of Germany's V-Weapons in World War II* (Rockville Centre, NY: Sarpedon, 1998).

39. R. V. Jones, *The Wizard War: British Scientific Intelligence, 1939–1945* (New York: Coward, McCann, and Geoghegan, 1978).

looking skeptically at von Braun and at the use of slave labor in World War II began to appear in the late 1990s. The two best of these sources are Andre Sellier's *A History of the Dora Camp* and Jean Michel's *Dora*.[40] Others include Yves Beon's *Planet Dora* and Dennis Piszkiewicz's *Wernher von Braun: The Man Who Sold the Moon*.[41] The journey of von Braun's team to the United States and other nations is the subject of a variety of literature, including works by Huzel, Lasby, Bower, Freeman, and Vilain.[42]

Early overviews of rocketry, which unavoidably discuss military involvement, include Zim's *Rockets and Jets*; Vaeth's *200 Miles Up*; Caidin's *Rockets and Missiles*; Emme's edited *History of Rocket Technology*; Baker's *The Rocket*; von Braun, Ordway, and Dooling's *History of Rocketry and Space Travel*; Winter's *Rockets into Space*; and Alway's *Rockets of the World*.[43]

The origins of American rocket and ballistic missile programs are well documented. The best overview of the early USAF missile programs remains Jacob Neufeld's internal Air Force history, *Ballistic Missiles in the United States Air Force, 1945–1960*. Older works also discuss the early ballistic missile programs, such as Schwiebert's *A History of the U.S. Air Force Ballistic Missiles*, Bergaust's *Rockets of the Armed Forces*, Neal's popular work on Minuteman, Chapman's early history of Atlas, Rosen's narrative of the Navy's Viking, Green and Lomask's history of Vanguard, and Hartt's story of the Thor missile. Thor and Atlas are described by Wambolt. Martin's series on Atlas is informative. A more recent work is Stine's 1991 *ICBM*. Greene's early internal history of Titan is still valuable. The most detailed recent historical study of a single program is Stumpf's *Titan II*. Titan's evolution is also described by

40. Andre Sellier, *A History of the Dora Camp* (Chicago: Ivan R. Dee, 2003); Jean Michel, *Dora* (New York: Holt, Rinehart, and Winston, 1980).

41. Yves Béon, *Planet Dora: A Memoir of the Holocaust and the Birth of the Space Age* (Boulder, CO: Westview Press, 1998); Dennis Piszkiewicz, *Wernher von Braun: The Man Who Sold the Moon* (Westport, CT: Praeger Publishers, 1998).

42. D. K. Huzel, *Peenemünde to Canaveral* (Englewood Cliffs, NJ: Prentice-Hall, 1962); Clarence G. Lasby, *Project Paperclip: German Scientists and the Cold War* (New York: Atheneum, 1971); Tom Bower, *The Paper Clip Conspiracy* (Boston: Little, Brown and Company, 1987); Marsha Freeman, *How We Got to the Moon: The Story of the German Space Pioneers* (Washington, DC: 21st Century Associates, 1993); J. Vilain, "France and the Peenemunde Legacy," in *History of Rocketry and Astronautics*, ed. P. Jung, American Astronautical Society History Series, vol. 21 (San Diego: Univelt Press, 1997), pp. 119–161.

43. Herbert H. Zim, *Rockets and Jets* (New York: Harcourt Brace & Company, 1945); J. Gordon Vaeth, *200 Miles Up: The Conquest of the Upper Air* (New York: The Ronald Press Company, 1951); Martin Caidin, *Rockets and Missiles: Past and Future* (New York: The McBride Company, 1954); Eugene Emme, ed., *The History of Rocket Technology* (Detroit: Wayne State University Press, 1964); David Baker, *The Rocket: The History and Development of Rocket and Missile Technology* (New York: Crown Books, 1978); Wernher von Braun, Frederick I. Ordway III, and Dave Dooling, *History of Rocketry and Space Travel* (New York: Thomas Y. Crowell, 1986); Frank H. Winter, *Rockets into Space* (Cambridge, MA: Harvard University Press, 1990); Peter Alway, *Rockets of the World* (Ann Arbor, MI: Saturn Press, 1992).

Falconer, as well as Richards and Powell. Reed's dissertation is an outstanding study of Minuteman. The Navaho, although a cruise missile, was crucial for rocket engine technology and is analyzed by Gibson. Two early works focused on ballistic missile operations are by Hunter, and Baar and Howard. Powell describes Blue Scout, a military research vehicle, Project Farside, an early USAF balloon rocket program, and the obscure Draco launcher. The Association of Air Force Missileers publishes a newsletter and has a Web site that frequently contains missile stories and historical information.[44]

Older political studies started analytical assessments of ballistic missiles and remain useful, such as the works of Armacost, Beard, and Sapolsky[45] on the 1950s American intermediate-range ballistic missile (IRBM), ICBM, and submarine-launched ballistic missile programs. Reed's dissertation on the politics of Minuteman is valuable.[46] Lonnquest and Winkler coauthored *To Defend*

44. Jacob Neufeld, *Ballistic Missiles in the United States Air Force, 1945–1960* (Washington, DC: Office of Air Force History, USAF, 1990); Ernest G. Schwiebert, *A History of the U.S. Air Force Ballistic Missiles* (New York: Frederick A. Praeger, 1964); Erik Bergaust, *Rockets of the Armed Forces* (New York: Putnam, 1966); Roy Neal, *Ace in the Hole: The Story of the Minuteman Missile* (Garden City, NY: Doubleday, 1962); John L. Chapman, *Atlas: The Story of a Missile* (New York: Harper & Brothers, 1960); Milton Rosen, *The Viking Rocket Story* (New York: Harper & Brothers, 1955); Constance McLaughlin Green and Milton Lomask, *Vanguard: A History* (Washington, DC: NASA SP-4202, 1970); Julian Hartt, *The Mighty Thor* (New York: Duell, Sloan, and Pearce, 1961); Joseph F. Wambolt, "Medium Launch Vehicles for Satellite Delivery," *Crosslink* 4, no. 1 (winter 2002/2003): 26–31; Richard E. Martin, "A Brief History of the Atlas Rocket Vehicle, Part 1," *Quest: The History of Spaceflight Quarterly* 8, no. 2 (2000): 54–61; Richard E. Martin, "A Brief History of the Atlas Rocket Vehicle, Part 2," *Quest: The History of Spaceflight Quarterly* 8, no. 3 (2000): 40–45; Richard E. Martin, "A Brief History of the Atlas Rocket Vehicle, Part 3," *Quest: The History of Spaceflight Quarterly* 8, no. 4 (2000): 46–51; G. Harry Stine, *ICBM: The Making of the Weapon that Changed the World* (New York: Orion Books, 1991); W. E. Greene, *The Development of the SM-68 Titan*, AFSC Historical Publications Series 62-23-1 (Wright-Patterson AFB, OH: Air Force Systems Command, 1962); David K. Stumpf, *Titan II: A History of a Cold War Missile Program* (Fayetteville: The University of Arkansas Press, 2000); Art Falconer, "Epic Proportions: The Titan Launch Vehicle," *Crosslink* 4, no. 1 (winter 2002/2003): 32–37; G. R. Richards and J. W. Powell, "Titan 3 and Titan 4 Space Launch Vehicles," *Journal of the British Interplanetary Society* 46, no. 4 (1993): 123–144; George A. Reed, "U.S. Defense Policy, U.S. Air Force Doctrine and Strategic Nuclear Weapon Systems, 1958–1964: The Case of the Minuteman ICBM" (Ph.D. diss., Duke University, 1986); James N. Gibson, *The Navaho Missile Project: The Story of the "Know-How" Missile of American Rocketry* (Atglen, PA: Schiffer Military/Aviation History, 1996); Mel Hunter, *The Missilemen* (Garden City, NY: Doubleday, 1960); James J. Baar and William E. Howard, *Combat Missilemen* (New York: Harcourt, 1961); Joel Powell, "Blue Scout—Military Research Rocket," *Journal of the British Interplanetary Society* 35, no. 1 (1982): 22–30; Joel W. Powell, "Project Farside, America's First Space Venture," *Journal of the British Interplanetary Society* 35, no. 10 (1982): 462–466; Joel W. Powell, "The Curious Case of Draco and the 'Secret' Cape Canaveral Launches of 1959," *Quest: The History of Spaceflight Quarterly* 6, no. 1 (1998): 44–46.

45. Michael H. Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy* (New York: Columbia University Press, 1969); Edmund Beard, *Developing the ICBM: A Study in Bureaucratic Politics* (New York: Columbia University Press, 1976); Harvey M. Sapolsky, *The Polaris System Development: Bureaucratic and Programmatic Success in Government* (Cambridge, MA: Harvard University Press, 1972).

46. Reed, "U.S. Defense Policy."

and Deter,[47] which provides technical details and overviews of all major U.S. programs. Lonnquest's dissertation was a focused study on General Bernard Schriever's role in Atlas.[48] Koppes's history of the Jet Propulsion Laboratory (JPL) remains a good introduction to its Army-funded rocketry and ballistic missile programs.[49] Spinardi provides an overview of the U.S. Navy's submarine-based ballistic missile programs,[50] as does Fuhrman.[51] Friedman's *The Evolution of Nuclear Strategy* remains a valuable work about nuclear warfare in general,[52] as is Kaplan's *The Wizards of Armageddon*.[53] There are no major publications on recent U.S. ballistic missile history beyond 1970, although there are many political science and politically motivated studies of arms control and disarmament.

Soviet ballistic missile history has gotten a major boost since the end of the Cold War. The foremost work is currently Zaloga's outstanding study, *The Kremlin's Nuclear Sword*,[54] which provides an overview of Soviet nuclear forces from 1945 to 2000. Zaloga's earlier study *Target America* also remains useful.[55] Also useful is Podvig's *Russian Strategic Nuclear Forces*.[56] Siddiqi's *Challenge to Apollo*, originally published by NASA and now published commercially, covers in depth the early ballistic missile development of Korolev's design bureau from the R1 to the R7.[57] Siddiqi also covers the development and deployment of a Soviet Fractional Orbiting Bombardment System (FOBS).[58] The Yangel design bureau was selected to build the R-36-O FOBS over competing proposals by the Korolev and Chelomey design bureaus. This system, which deployed 18 missiles from 1971 to 1983, placed a nuclear warhead in

47. John C. Lonnquest and David F. Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program*, Special Report 97/01 (Champaign, IL: U.S. Army Construction Engineering Research Laboratories, 1996).

48. John Lonnquest, "The Face of Atlas: General Bernard Schriever and the Development of the Atlas Intercontinental Ballistic Missile, 1953–1960" (Ph.D. diss., Duke University, 1996).

49. Clayton R. Koppes, *JPL and the American Space Program: A History of the Jet Propulsion Laboratory* (New Haven, CT: Yale University Press, 1982).

50. Graham Spinardi, *From Polaris to Trident: The Development of U.S. Fleet Ballistic Missile Technology* (New York: Cambridge University Press, 1994).

51. R. A. Fuhrman, "The Fleet Ballistic Missile System: Polaris to Trident," *Journal of Spacecraft* 15, no. 5 (1978): 265–286.

52. Lawrence Friedman, *The Evolution of Nuclear Strategy* (New York: St. Martin's Press, 1983).

53. Fred Kaplan, *The Wizards of Armageddon* (Stanford: Stanford University Press, 1983).

54. Steven Zaloga, *The Kremlin's Nuclear Sword: The Rise and Fall of Russia's Strategic Nuclear Forces, 1945–2000* (Washington, DC: Smithsonian, 2002).

55. Steven J. Zaloga, *Target America: The Soviet Union and the Strategic Arms Race, 1945–1994* (Novato, CA: Presidio, 1993).

56. P. Podvig, *Russian Strategic Nuclear Forces* (Cambridge, MA: MIT Press, 2001).

57. Asif A. Siddiqi, *Sputnik and the Soviet Space Challenge* (Gainesville: University of Florida Press, 2003); Asif A. Siddiqi, *The Soviet Space Race with Apollo* (Gainesville: University of Florida Press, 2003).

58. Asif A. Siddiqi, "The Soviet Fractional Orbiting Bombardment System (FOBS): A Short Technical History," *Quest: The History of Spaceflight Quarterly* 7, no. 4 (1999): 22–33.

temporary orbit, going over the South Pole to evade American early-warning radars and then deorbiting quickly to hit the United States. Harford's *Korolev* also has a significant amount of information about the early ballistic missile programs.[59] Barry's Ph.D. dissertation, "The Missile Design Bureaux and Soviet Piloted Space Policy," describes some political aspects of early design bureaus.[60] Zak wrote a short piece on the origins of the Cosmos launcher.[61]

China's early ballistic missile program is tied to the story of Tsien Hsue-Shen, which is chronicled in Chang's *Thread of the Silkworm*.[62] Harvey's *The Chinese Space Programme* provides an overview of ballistic missile and launcher developments.[63] Lewis also describes the Chinese ballistic missile programs.[64]

Histories of other nations' ballistic missile programs and their transformation to launchers remain far less documented. The British program is the one major exception, with Morton's *Fire across the Desert*, Twigge's *The Early Development of Guided Weapons in the United Kingdom, 1940–1960*, Hill's *A Vertical Empire*, and Martin's *De Havilland Blue Streak*.[65] A recent article on early French missile and launcher efforts is by Huwart.[66]

The single best source for the history of U.S. space launchers is Launius and Jenkins's edited work, *To Reach the High Frontier*, which has articles on all major American launch programs.[67] This work also has an overview of the evolution of the Minuteman ICBM program by Hunley. Isakowitz is now up to the fourth edition of his *International Reference Guide to Space Launch Systems*; tracing the evolution of these editions provides historians with a thorough grounding in the technical aspects of the subject.[68] Hall provides an overview of the military ori-

59. James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, 1997).

60. William P. Barry, "The Missile Design Bureaux and Soviet Piloted Space Policy, 1953–1974" (Ph.D. diss., University of Oxford, 1995).

61. Anatoly Zak, "Cosmos Launcher: The Story of the Soviets' Space Workhorse," *Spaceflight* 38, no. 12 (1996): 416–418.

62. Iris Chang, *Thread of the Silkworm* (New York: Basic Books, 1995).

63. Brian Harvey, *The Chinese Space Programme: From Conception to Future Capabilities* (New York: John Wiley & Sons, 1998).

64. J. D. Lewis and H. Di, "China's Ballistic Missile Programs," *International Security* 17, no. 2 (1992): 5–40.

65. Peter Morton, *Fire across the Desert: Woomera and the Anglo-Australian Joint Project, 1946–1980* (Canberra: Australian Government Publishing Services, 1989); Stephen Robert Twigge, *The Early Development of Guided Weapons in the United Kingdom, 1940–1960* (Chur, Switzerland: Harwood Academic Publishers, 1993); C. N. Hill, *A Vertical Empire: The History of the UK Rocket and Space Programme, 1950–1971* (London: Imperial College, World Scientific, 2001); Charles H. Martin, *De Havilland Blue Streak: An Illustrated Story* (London: British Interplanetary Society, 2002).

66. Olivier Huwart, "Du V-2 à Veronique: Les Premières Recherches Spatiales Militaires Françaises," *Review Historiques des Armées* 3 (1997): 113–126.

67. Roger D. Launius and Dennis R. Jenkins, eds., *To Reach the High Frontier: A History of U.S. Launch Vehicles* (Lexington: The University Press of Kentucky, 2002).

68. Steven J. Isakowitz, Joshua B. Hopkins, and Joseph P. Hopkins, Jr., *International Reference Guide to Space Launch Systems*, 4th ed. (Reston, VA: AIAA, 2004).

gins of Agena in the CORONA program.[69] Siddiqi chronicles some of the conversions of Soviet ballistic missiles to launchers in *Challenge to Apollo*.[70] Harvey's *Russia in Space* gives a good overview of Russian launch systems.[71] Bille and Lishock describe early military launchers, including the obscure NOTSNIK, a designation combining the acronym for Naval Ordnance Test Station and Sputnik.[72] NOTSNIK received attention earlier from Pesavento and Powell.[73]

Military involvement with space transportation also includes the development of hypersonic and reusable systems. Overviews of hypersonics include Caidin's early *Wings into Space*, the two volumes of *The Hypersonic Revolution*, and Miller's *The X-Planes*.[74] The X-15 story dominates the early history of military reusable systems, and has garnered significant attention in the last two years. These include works by Jenkins, by Jenkins and Landis, Thompson, the reprint of Tregaskis, and Godwin.[75] *Quest* issue 3, number 1, has a number of articles on the X-15.

The Air Force's abortive Dyna-Soar program, later renamed the X-20, is discussed in Spires's *Beyond Horizons* and received historical attention in *Quest* issue 3, number 4, with articles by Houchin and Smith.[76] Houchin's work is

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69. R. Cargill Hall, "The Air Force Agena: A Case Study in Early Spacecraft Technology," in *Technology and the Air Force: A Retrospective Assessment*, ed. Jacob Neufeld, George M. Watson, Jr., and David Chenoweth (Washington, DC: Air Force History and Museums Program, 1997), pp. 231–244.

70. Asif A. Siddiqi, *Challenge to Apollo*.

71. Brian Harvey, *Russia in Space: The Failed Frontier?* (Chichester, U.K.: Praxis Publishing, 2001).

72. Matt Bille and Erika Lishock, *The First Space Race: Launching the World's First Satellites* (College Station: Texas A&M Press, 2004).

73. Peter Pesavento, "US Navy's Untold Story of Space-Related Firsts: Space Projects of the Naval Ordnance Test Station (NOTS)," *Spaceflight* 38, no. 7 (1996): 239–243; Peter Pesavento, "Secrets Revealed About the Early US Navy Space Programme," *Spaceflight* 38, no. 7 (1996): 243–245; J. Powell, "The NOTS Air-Launched Satellite Programme," *Journal of the British Interplanetary Society* 50, no. 11 (1997): 433–440.

74. Martin Caidin, *Wings into Space: The History and Future of Winged Space Flight* (New York: Holt, Rinehart, and Winston, 1964); *The Hypersonic Revolution: Case Studies in the History of Hypersonic Technology*, vol. 1, *From Max Valier to Project PRIME (1924–1967)* (Bolling AFB, Washington, DC: USAF History and Museums Program, 1998); *The Hypersonic Revolution: Eight Case Studies in the History of Hypersonic Technology*, vol. 2, *From Scramjet to the National Aero-Space Plane* (Dayton, OH: Special Staff Office, Aeronautical Systems Division, Wright-Patterson AFB, 1987); Jay Miller, *The X-Planes: X-1 to X-45* (Stillwater, MN: Voyageur Press, 2001).

75. Dennis R. Jenkins, *Hypersonics Before the Shuttle: A Concise History of the X-15 Research Airplane* (Washington, DC: NASA SP-2000-4518, 2000); Dennis R. Jenkins and Tony Landis, *Hypersonic: The Story of the North American X-15* (North Branch, MN: Specialty Press, 2003); Milton O. Thompson, *At the Edge of Space: The X-15 Flight Program* (Washington, DC: Smithsonian Institution Press, 2003); Richard Tregaskis, *The X-15 Diary: The Story of America's First Space Ship* (New York: Dutton, 1961; reprint, Lincoln: University of Nebraska Press, 2004); Robert Godwin, *X-15—The NASA Mission Reports Incorporating Files from the USAF* (Burlington, Ontario: Apogee Books, 2000).

76. Roy F. Houchin II, "Why the Air Force Proposed the Dyna-Soar X-20 Program," *Quest: The History of Spaceflight Magazine* 3, no. 4 (winter 1994): 5–12; Roy F. Houchin II, "Why the Dyna-

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based on his dissertation, and he also has a more recent article on Dyna-Soar in the *Journal of the British Interplanetary Society.*[77] Strom has a short introduction to Dyna-Soar in *Crosslink.*[78] Apogee's series of historic space document publications includes Godwin's collection for Dyna-Soar.[79]

Russell Hannigan's *Spaceflight in the Era of Aero-Space Planes* was the first general work on the topic.[80] Reed and Thompson both describe USAF involvement with lifting-body research.[81] Schweikart describes the USAF's efforts for an orbital reusable system in his *Quest for the Orbital Jet.*[82] Butrica documents later military efforts to build reusable systems in his *Single Stage to Orbit.*[83] It is also important to note the military's involvement with the Space Shuttle program, both in its design and in its operations. These are currently best documented in T. A. Heppenheimer's two recent volumes and are also noted in David Spires's overview of the U.S. Air Force in space, *Beyond Horizons.*[84] Tomei discusses the USAF Space Shuttle program.[85] The Inertial Upper Stage, developed to support the Space Shuttle program, is described by Dunn.[86]

The military was also crucial in the development of the various technologies of rocketry. Military funding of liquid-propellant and solid-propellant engines was the starting point for rocketry. The various stories of rocket pio-

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Soar X-20 Program was Cancelled," *Quest: The History of Spaceflight Magazine* 3, no. 4 (winter 1994): 35–37; Terry Smith, "The Dyna-Soar X-20: A Historical Overview," *Quest: The History of Spaceflight Magazine* 3, no. 4 (winter 1994): 13–18; Terry Smith, "Dyna-Soar X-20: A Look at Hardware and Technology," *Quest: The History of Spaceflight Magazine* 3, no. 4 (winter 1994): 23–28.

77. Roy Franklin Houchin II, "The Rise and Fall of Dyna-Soar: A History of Air Force Hypersonic R&D, 1944–1963" (Ph.D. diss., Auburn University, 1995); Roy F. Houchin II, "Air Force-Office of the Secretary of Defense Rivalry: The Pressure of the Political Affairs in the Dyna-Soar (X-20) Program, 1957–1963," *Journal of the British Interplanetary Society* 50 (May 1997): 162–168.

78. Steven R. Strom, "Jurassic Technology: The History of the Dyna-Soar," *Crosslink* 5, no. 1 (winter 2003/2004): 6–9.

79. Robert Godwin, *Dyna-Soar: Hypersonic Strategic Weapon System* (Burlington, Ontario: Apogee Books, 2001).

80. Russell J. Hannigan, *Spaceflight in the Era of Aero-Space Planes* (Malabar, FL: Krieger Publishing, 1994).

81. R. Dale Reed with Darlene Lister, *Wingless Flight: The Lifting Body Story* (Washington, DC: NASA SP-4220, 1997); Milton O. Thompson and Curtis Peebles, *Flying Without Wings: NASA Lifting Bodies and the Birth of the Space Shuttle* (Washington, DC: Smithsonian Institution Press, 1999).

82. Larry Schweikart, *The Quest for the Orbital Jet* (Washington, DC: USAF History and Museums Program, 1998).

83. Andrew J. Butrica, *Single Stage to Orbit: Politics, Space Technology, and the Quest for Reusable Rocketry* (Baltimore, MD: Johns Hopkins, 2003).

84. T. A. Heppenheimer, *The Space Shuttle Decision: NASA's Search for a Reusable Space Vehicle* (Washington, DC: NASA SP-4221, 1999); T. A. Heppenheimer, *Development of the Space Shuttle, 1972–1981: History of the Space Shuttle*, vol. 2 (Washington, DC: Smithsonian Institution Press, 2002); Spires, *Beyond Horizons.*

85. E. J. Tomei, "The Air Force Space Shuttle Program: A Brief History," *Crosslink* 4, no. 1 (winter 2002/2003): 22–25.

86. W. Paul Dunn, "The Evolution of the Inertial Upper Stage," *Crosslink* 4, no. 1 (winter 2002/2003): 38–42.

neers (not repeated here), who were mostly funded by the military, invariably describe the early travails in the development of liquid and solid propellants. Volume 13 in the AAS History Series, edited by Doyle, provides a number of papers on the history of liquid-propellant rocketry.[87] Heppenheimer describes the key role of the Navaho program in American liquid-propellant rocketry.[88] The best work on solid-propellant rocketry in the United States has been done by Hunley.[89] McKenzie's sociological study of nuclear missile guidance, *Inventing Accuracy*, remains the best study of this aspect of ballistic missiles.[90] Martin describes the development of the balloon tank structure of Atlas.[91] The evolution of reentry systems is described by Hartunian.[92]

Cleary provides two volumes on military operations at Cape Canaveral.[93] Guillemette describes the history of Space Launch Complex 6 at Vandenberg AFB.[94] Day provides an unusual look at the archaeology of Vandenberg Air Force Base in a two-part series in *Spaceflight*.[95] Powell and Scala tell story of White Sands Missile Range, and Powell describes its Green River Annex.[96] With the end of the Cold War, there have been a number of Historic American Engineering Record surveys of U.S. missile and space sites, such as Lauber and Hess's survey of the Denver Titan site.[97] Boxx describes the development of Woomera.[98]

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87. S. E. Doyle, ed., *History of Liquid Rocket Engine Development in the United States: 1955–1980*, American Astronautical Society History Series, vol. 13 (San Diego: Univelt Press, 1992).

88. Thomas A. Heppenheimer, "The Navaho Program and the Main Line of American Liquid Rocketry," *Air Power History* 44, no. 2 (1997): 4–17.

89. J. D. Hunley, "The Evolution of Large Solid Propellant Rocketry in the United States," *Quest: The History of Spaceflight Quarterly* 6, no. 1 (1998): 22–39. See also Hunley's article on Minuteman in Launius and Jenkins, *To Reach the High Frontier*.

90. Donald McKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, MA: MIT Press, 1990).

91. R. E. Martin, "The Atlas and Centaur 'Steel Balloon' Tanks. A Legacy of Karel Bossart," IAA Paper 82-738 (40th Congress of International Astronautical Federation, Malaga, Spain, 7–12 October 1989).

92. Richard A. Hartunian, "Ballistic Missiles and Reentry Systems: The Critical Years," *Crosslink* 4, no. 1 (winter 2002/2003): 5–9.

93. Cleary, *The 6555th*; Cleary, *The Cape*.

94. Roger Guillemette, "Vandenberg: Space Shuttle Launch and Landing Site, Part 1, Construction of Shuttle Launch Facilities," *Spaceflight* 36, no. 10 (1994): 354–357; Roger Guillemette, "Vandenberg: Space Shuttle Launch and Landing Site, Part 2, Abandoned in Place," *Spaceflight* 36, no. 11 (1994): 378–381.

95. Dwayne A. Day, "Relics of the Space Race: Space Archeology at Vandenberg Air Force Base, Part 1," *Spaceflight* 42, no. 2 (2000): 59–62; Dwayne A. Day, "Relics of the Space Race: Space Archeology at Vandenberg Air Force Base, Part II," *Spaceflight* 42, no. 3 (March 2000): 120–122.

96. J. W. Powell and K. J. Scala, "Historic White Sands Missile Range," *Journal of the British Interplanetary Society* 47, no. 3 (1994): 83–98; Joel W. Powell, "Green River, Utah: a Forgotten Annex of White Sands Missile Range," *Spaceflight* 43, no. 3 (2001): 123–125.

97. John F. Lauber and Jeffrey A. Hess, *Glenn L. Martin Company Titan Missile Test Facilities, Denver, Colorado*, Historic American Engineering Record (HAER) #CO-75 (Minneapolis, MN: Hess, Roice and Company, December 1993).

98. Isaac G. Boxx, "Woomera, Part 1," *Spaceflight* 37, no. 6 (1995): 200–202; Isaac G. Boxx, "Woomera, Part 2," *Spaceflight* 37, no. 7 (1995): 243–247.

Early Warning and Space Surveillance

Response to an attack by ballistic missiles first requires warning that an attack is under way and the ability to discriminate between these and other natural or humanmade objects that reenter the atmosphere. Given that the flight time of intercontinental ballistic missiles from the U.S. to the USSR and vice versa is about 30 minutes and that defenses against missiles have remained extremely difficult, the main purpose of these systems was to send warning to the political and military leaders to command a retaliatory strike. In practice, this meant launching ballistic missiles, getting bombers into the air, and sending signals to submarine forces. Both the United States and Soviet Union developed ground-based and space-based systems for these purposes at the same time as ballistic missiles became viable as operational weapons.

During World War II, radar systems in the United States were developed mainly at Massachusetts Institute of Technology's (MIT) Radiation Laboratory, which developed a variety of ground-, ship-, and aircraft-based radar systems to detect enemy aircraft and submarines and also to aid strategic bombing. After the war, the threat of Soviet nuclear-armed bombers spurred the creation of progressively more powerful radar systems, along with the need to connect the many radar systems together across increasingly larger regions, eventually to protect the entire North American continent. The problem of rapidly correlating these data as aircraft speeds increased led researchers at the MIT Radiation Laboratory and at the University of Michigan to develop computer-based technologies to integrate the variety of data for each air defense sector. The USAF ultimately selected MIT's system, which became known as the Semi-Automatic Ground Environment (SAGE) system. SAGE became the most expensive computer and largest software programming effort of the 1950s. Unfortunately, the Soviet Union quickly made it obsolete by creating ballistic missiles.

To detect ballistic missiles, the SAGE system was inadequate. What the United States needed was a large, over-the-horizon radar that could pick up ballistic missile launches as early as possible in their flight trajectories. The new system, called the Ballistic Missile Early Warning System (BMEWS), whose first radar system in Thule, Greenland, began operation on 31 December 1960, could detect ballistic missiles launched from the Soviet Union 15 minutes prior to impact. This provided a bare minimum of time for the United States to retaliate by getting its bombers and ballistic missiles into the air before impact. Phased-array radar systems, including the PAVE PAWS and COBRA DANE systems of the 1970s and 1980s, were later implemented to improve capabilities to track multiple objects and to detect submarine-launched ballistic missiles.

Such a short response time was problematic, and the USAF sought any means to extend it. By the late 1950s, satellites beckoned as a possibility. Building off of infrared sensor technologies developed in Nazi Germany, Lockheed

An Agena A spacecraft for an early MIDAS launch undergoes a weight test in 1960 at Lockheed's plant in Sunnyvale, California, before shipment to Cape Canaveral for launch. *(Official USAF photo. Air Force Space Command, Office of History)*

Corporation proposed a variant of its military satellite project, Weapon System 117L (WS-117L), that could detect the infrared signature of a ballistic missile's rocket exhaust plume in the first few minutes of flight. This experimental project, called the Missile Defense Alarm System (MIDAS), placed infrared detectors on polar-orbiting satellites. Despite many failures, to the surprise of its many skeptics, MIDAS proved that the technology was viable. Improvements in the detector technologies allowed the USAF to put out requests for an operational geosynchronous system of three satellites that could monitor the entire globe. Eventually called the Defense Support Program (DSP), this program has gone through several upgrades since the early 1970s and remains functional today. DSP gained notoriety during the Gulf War of 1991 when it detected Iraqi short-range ballistic missile launches. Based on this experience, DSP has been tied more closely to tactical users, as shown in the Iraq War of 2003, when it relayed missile launch data to U.S. Central Command. It is currently to be replaced in the late 2000s by the Space-Based Infrared System (SBIRS).

The Soviet Union went through a similar evolution from local to continental radars for air defense, and then ballistic missile detection, and finally to space-based systems. In the 1960s, the Soviets developed the Dnestr and Dnepr systems. The late 1970s and 1980s saw the deployment of the more powerful Daryal radars into operation, one of which was the Krasnoyarsk system that became a focus of controversy when the United States accused the Soviet Union of violating the Anti-Ballistic Missile Treaty by aiming this radar east across Siberia instead of across national borders as the treaty required. The Soviets also deployed three powerful over-the-horizon Duga-2 systems in the 1970s. Finally, the Lavotchkin design bureau developed early-warning satellites, first a constellation of Molniya orbit satellites called Oko, in the 1970s, and a geosynchronous system called Prognoz, first deployed in the 1980s. Oko deployed a nine-satellite constellation with its apogee above North America and Europe to ensure satellites were deployed over these regions at all times. The fall of the Soviet Union has caused major problems with the early-warning system, as some of the ground-based radar sites were located in newly independent Baltic States that refused to operate them. In addition, the financial crises associated with the fall of the communist empire meant that the Oko and Prognoz constellations have not been fully maintained. The combination of these problems means that the now-Russian system has significant gaps in coverage.

The American and Soviet navies both came to rely on space-based surveillance of the oceans to identify the location of each other's fleets for both strategic and tactical purposes. Significantly outgunned by the U.S. Navy, the Soviet Union relied far more on submarines and ground-based aircraft for its naval goals and developed naval surveillance satellites to augment these capabilities. Its US-A (active radar—RORSAT, Radar Ocean Reconnaissance Satellite) and US-P (passive radar—EORSAT, Electronic Intelligence Ocean Reconnaissance Satellite) systems, designed by Vladimir Chelomey's OKB-52, were deployed in the 1970s. The United States also saw the utility in a naval satellite system, also developing and deploying its White Cloud satellites in the 1970s. White Cloud, US-P, and their descendants remain active in the early 21st century, but US-A's last launch was in 1988, and the program is now defunct.

Both the United States and the Soviet Union also had to distinguish between ballistic missiles and natural or artificial debris reentering the atmosphere. Neither side desired to launch a nuclear strike to retaliate against a meteor or old spacecraft burning up in the atmosphere. Starting in the late 1950s, both sides began to develop space surveillance networks that used combinations of active radar and passive optical and electronic sensors to monitor the trajectories of Earth-orbiting satellites and associated debris.

Early-warning systems are most frequently encountered in books with larger goals. The best starting point to understand radar's development from prior to World War II into the early Cold War is Buderi's *The Invention that Changed the World*.[99] The best source for an overview of the U.S. systems is Spires's *Beyond Horizons*,[100] which contains descriptions of the USAF ground- and space-based early-warning systems. Schaffel's *The Emerging Shield* gives the prehistory of the air defense systems from the end of World War II to 1960, including the various radar systems.[101] Winkler gives an overview of both air defense and missile warning radar systems.[102] Needell's biography of Lloyd Berkner contains a chapter on his role in the development of the Distant Early Warning (DEW) line in the Arctic.[103] Klass was among the first to discuss MIDAS in his *Secret Sentries in Space* in 1971.[104] Sprague's 1985 study of MIDAS at Air University is another early work.[105] The National Reconnaissance Office recently declassified Hall's history of MIDAS, originally written in 1989, but which was publicly published in 1999 both by the NRO and in *Quest*.[106] N. W. Watkins published a short history of MIDAS after Hall's work was written but before it was publicly released.[107] Day published a three-part series on DSP in 1996.[108] Richelson's *America's Space Sentinels* is one

99. Robert Buderi, *The Invention that Changed the World* (New York: Simon & Schuster, 1996).

100. Spires, *Beyond Horizons*.

101. Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945–1960* (Washington, DC: Office of Air Force History, 1991).

102. David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Langley AFB, VA: HQ Air Combat Command, 1997).

103. Allan A. Needell, *Science, Cold War and the American State: Lloyd V. Berkner and the Balance of Professional Ideals* (Amsterdam: Harwood Academic Publishers, 2000), chap. 9.

104. Philip J. Klass, *Secret Sentries in Space* (New York: Random House, 1971).

105. Major Barkley G. Sprague, *Evolution of the Missile Defense Alarm System, 1955–1982* (Maxwell AFB, AL: Air Command and Staff College, Air University, 1985).

106. R. Cargill Hall, *Missile Defense Alarm: The Genesis of Space-Based Infrared Early Warning* (Washington, DC: NRO History Office, July 1988); R. Cargill Hall, "Missile Defense Alarm: The Genesis of Space-based Infrared Early Warning," *Quest: The History of Spaceflight Quarterly* 7, no. 1 (spring 1999): 5–17.

107. N. W. Watkins, "The MIDAS Project Part 1: Strategic and Technical Origins and Political Evolution, 1955–1963," *Journal of the British Interplanetary Society* 50, no. 6 (1997): 215–224.

108. Dwayne A. Day, "Top Cover: The Origins and Evolution of the Defense Support Program, Part 1," *Spaceflight* (January 1996): 22–26; Dwayne A. Day, "Top Cover: The Origins and Evolution of the Defense Support Program, Part 2," *Spaceflight* (February 1996): 59–63; Dwayne A. Day, "Top Cover: The Origins and Evolution of the Defense Support Program, Part 3," *Spaceflight* (March 1996): 95–99.

of the few books devoted to the topic, in this case to the genesis and evolution of American early-warning systems, starting with MIDAS, but focusing on the DSP system.[109] Since DSP had a ground control center in Australia, Ball's *Base for Debate* was an early monograph that described DSP, among other systems.[110] An obscure but useful source produced when the Woomera DSP facility was closed is Erickson's *The History of the JDFN (Joint Defence Facility Nurrungar)*.[111] Rosolanka created a short pictorial history of DSP.[112]

The best source for the Soviet and Russian program is Zaloga's *The Kremlin's Nuclear Sword*, which contains descriptions and development history of all Soviet and Russian ground- and space-based early-warning systems.[113] Another good overview is part 2 of Whitmore's "Red Bear on the Prowl."[114] Harvey's *Russia in Space* provides a brief description of Oko and Prognoz.[115] Kagan also describes Soviet early-warning satellites, as does Forden.[116] A description of the various post–Cold War gaps in the Russian system is given in Forden, Podvig, and Postol's "False Alarm, Nuclear Danger"[117] and in Clark's "Decline of the Russian Early Warning System."[118]

United States and Soviet/Russian naval surveillance satellites are discussed, along with their implications for naval strategy and tactics, in Friedman's dense and informative *Seapower and Space*.[119] Siddiqi discusses the Soviet programs in a 1999 article in the *Journal of the British Interplanetary Society*.[120] Muse provides another recent treatment of RORSAT.[121] Teal Ruby, the failed Defense

109. Jeffrey T. Richelson, *America's Space Sentinels: DSP Satellites and National Security* (Lawrence: University Press of Kansas, 1999).

110. Desmond Ball, *A Base for Debate: The U.S. Satellite Station at Nurrungar* (North Sydney: Unwin Hymna, 1988).

111. Mark Erickson, ed., *The History of the JDFN (Joint Defence Facility Nurrungar), 1970–1999* (Woomera, Australia: 5th Space Warning Squadron and No. 1 Joint Communications Unit, 1999).

112. James J. Rosolanka, *The Defense Support Program (DSP): A Pictorial Chronology, 1970–1998* (Los Angeles AFB, CA: SBIRS System Program Office, 1998).

113. Zaloga, *The Kremlin's Nuclear Sword*.

114. Paul H. Whitmore, "Red Bear on the Prowl: Strategic Warning in the Soviet Union, Part 2," *Quest: The History of Spaceflight Quarterly* 10, no. 1 (2003): 54–62.

115. Harvey, *Russia in Space: The Failed Frontier?*

116. Boris Kagan, *Soviet ABM Early Warning System: Satellite-Based Project M* (Falls Church, VA: Delphic, 1991); Geoffrey Forden, "Russia's Early Warning System: Which Came First, Technology or Doctrine?" *Breakthroughs* 10, no. 1 (spring 2001): 9–16.

117. Geoffrey Forden, Pavel Podvig, and Theodore A. Postol, "False Alarm, Nuclear Danger," *Spectrum* 37, no. 3 (March 2000): 31–39.

118. Phillip Clark, "Decline of the Russian Early Warning System," *Jane's Intelligence Review* (January 2001).

119. Norman Friedman, *Seapower and Space: From the Dawn of the Missile Age to Net-Centric Warfare* (Annapolis, MD: Naval Institute Press, 2000).

120. Asif Siddiqi, "Staring at the Sea—The Soviet RORSAT and EORSAT Programme," *Journal of the British Interplanetary Society* 52 (1999): 397–416.

121. Fritz Muse, "RORSATS: The Veiled Threat," *Journal of the British Interplanetary Society* 57, supplement 1 (2004): 42–49.

Advanced Research Projects Agency (DARPA)–USAF effort to develop a satellite to monitor aircraft flight, is discussed by Day.[122]

There is no comprehensive published history of space surveillance, either American or Russian. Some early histories by Hayes, Thomas, and Engle and Drummond are now quite dated but describe passive satellite tracking in the early 1960s.[123] They also include a substantial amount on satellite command and control as it existed at the time. More recent information can be found in *Jane's Space Directory*.[124] An unpublished independent study project by Evans at the University of North Dakota used these sources and a few others to provide an overview history of the U.S. Space Surveillance Network.[125] Spires's *Beyond Horizons* provides some information on the history of the Space Surveillance Network as well.[126] Powell describes the Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) system.[127] The evolution of space surveillance into asteroid detection after the collision of Shoemaker-Levy 9 with Jupiter in 1994 is narrated by Mesco.[128] The history of the Soviet/Russian system remains undocumented, with only a couple of brief papers in English describing the system and even briefer mentions of its history.[129] An interesting case study of academic participation in space tracking is presented by Wikles and Gleditsch.[130] Another specific case study is the tracking of Cosmos 954, which fell on Canada in 1978.[131]

122. Dwayne A. Day, "Jewel in the Sky: The US Military Satellite that Never Made It," *Spaceflight* 47, no. 4 (2005): 147–154.

123. Eugene Hayes, *The Smithsonian's Satellite Tracking Program: Its History and Organization* (Washington, DC: Smithsonian, 1962); Shirley Thomas, *Satellite Tracking Facilities: Their History and Operation* (New York: Holt, 1963); Eloise Engle and Kenneth H. Drummond, *Sky Rangers: Satellite Tracking Around the World* (New York: John Day Co., 1965).

124. *Jane's Space Directory* (Alexandria, VA: Jane's Information Group, annual).

125. Brad M. Evans, "The History of the Space Surveillance Network and its Capabilities" (unpublished Independent Study Project, Department of Space Studies, University of North Dakota, summer 2003).

126. Spires, *Beyond Horizons*.

127. Joel Powell, "Satellite Tracking with GEODSS," *Spaceflight* 27, no. 3 (1985): 129–130.

128. James C. Mesco, "Watch the Skies," *Quest: The History of Spaceflight Quarterly* 6, no. 4 (1998): 35–40.

129. G. Batyr, S. Veniaminov, V. Dicky, V. Yurasov, A. Menshicov, Z. Khotorovsky, "The Current State of Russian Space Surveillance System and its Capability in Surveying Space Debris," paper no. ESA SD-01 in *Proceedings of the First European Conference on Space Debris* (held in Darmstadt, Germany, 5–7 April 1993, European Space Agency); Z. N. Khutorovsky**,** "Low-Perigee Satellite Catalog Maintenance: Issues of Methodology" (paper presented at the Second European Congress on Space Debris, Darmstadt, Germany, 17–19 March 1997).

130. Owen Wilkes and Nils Petter Gleditsch, "Optical Satellite Tracking: A Case Study in University Participation in Preparation for Space Warfare," *Journal of Peace Research* 15, no. 3 (1978): 205–225.

131. Leo Heaps, *Operation Morning Light: Terror in Our Skies, The Story of Cosmos 954* (London: Paddington Press, 1978).

Command and Control

Relaying data to and from space systems and ground centers in order to control these devices and to initiate and control military responses to strategic and tactical events is crucial to both nuclear and conventional warfare. With each generation and type of space vehicle, and in many cases with each specific project, are built operations control centers and mechanisms to integrate and analyze the data and to distribute the data coming from the space systems to appropriate people and groups on the ground. Despite the unquestioned fact that all space systems require ground control, this topic has received, with a few notable exceptions, remarkably little attention from historians or other scholars. Most studies focus on the devices that go into space, to the detriment of what happens on the ground to control them.

There are at least two types of ground control systems. The first type includes systems that directly control the operations of spacecraft. To do this, the engineering and sensor data are sent to the Earth (downlinked) from the spacecraft and distributed to a mission operations team, which then sends commands up (uplinked) to the spacecraft to control its operation. The second type includes systems that take the sensor data from spacecraft and then operate on and distribute those data for other functions. The best U.S. example of the former is the satellite command and control complexes at Schriever AFB near Colorado Springs, Colorado, the Air Force Satellite Control Facility. The best example of the latter are the military command and control facilities of the Cheyenne Mountain Complex, also near Colorado Springs, which receive sensor data from all around the world, combine them into an integrated picture of air and space threats to the North American continent, and then use and send those integrated data to decision-makers who must determine how to respond to any perceived threats.

The stories of the two types of ground control systems appear in different kinds of histories. The histories of ground control systems that operate spacecraft are, to the extent they exist at all, usually tied to the history of the projects and spacecraft for which they were built. Thus, in most cases, one finds the ground control story in the general histories of the projects for which they were created. In some cases, these ground control systems are modified to also control other spacecraft, in which case they take on lives of their own, partially separated from the specific systems they control. Such is the story of the Air Force Satellite Control Facility, which began as the facility that controlled the CORONA satellites but later expanded to control other spacecraft as well.

The histories of classical command and control systems such as those residing in Cheyenne Mountain are usually separate from the specific systems that contribute data because the point of these systems is to combine data from different systems and assemble it into formats usable to decision-makers. Thus

Space Defense Center inside Cheyenne Mountain, June 1984. *(Official USAF photo. Air Force Space Command, Office of History)*

the histories depend on sensor systems and higher level political and operational decisions as well as the specifics of the "combination" of the data.

The origins of the North American command and control system start with the early-warning systems described in the previous section. As various radar systems were developed and deployed around the northern periphery of the continent, the United States developed the first real-time computer to automate the translation of radar data into a "user-friendly" graphical interface that would allow Air Force enlisted personnel to identify incoming Soviet bombers and direct U.S. fighters and missiles to intercept them. This system, called the Semi-Automatic Ground Environment, or SAGE, was a major milestone in the development of computing hardware and software. Developed by the Lincoln Laboratory of the Massachusetts Institute of technology, SAGE led to the creation of the Air Force–funded, nonprofit MITRE Corporation to complete its development, and also the System Development Corporation, which spun off from RAND Corporation to create SAGE's software.

In 1957, Canada and the United States formed North American Air Defense Command, or NORAD, to jointly protect the continent, given that the radar systems needed to detect Soviet bombers were located on both U.S. and Canadian soil. The central command center was established at Ent Air Force Base in Colorado Springs, Colorado, that same year. In 1959, the U.S.

Joint Chiefs of Staff selected Cheyenne Mountain, just southwest of Colorado Springs, to be the location of an underground, nuclear-hardened facility to house NORAD. Into the tunnels of Cheyenne Mountain, which was completed in 1965, went the command facilities for the SAGE air defense network, the Ballistic Missile Early Warning System (BMEWS), and what became the Space Surveillance Network. Tying these three separate systems together into a single command center was the 425L Command Operations Center computing and display system, which used Philco 2000 computers. On 1 January 1966, Air Force Systems Command handed over operations to NORAD, whose commander, by treaty, was always an American, and whose deputy commander was always a Canadian. The NORAD Combat Operations Center became operational in February 1967 when the Space Defense Center system, 496L, was completed. Data from NORAD were fed to the American and Canadian national authorities.

Increases in Soviet threats and in corresponding American detection systems such as phased-array radars led to the Cheyenne Mountain Improvement Program, called 427M. This new system would have to integrate with a global command and control system, known as the World-Wide Military Command and Control System (WWMCCS), which used Honeywell Information System 6060 computers. Philco-Ford won a contract for system integration and testing, and the communications gear, while System Development Corporation won the contract for the Space Computation Center software and displays. The system also eventually included UNIVAC 1100/42 systems for satellite early warning. NORAD itself developed much of the system software. 427M was finally completed in 1979 but suffered some false nuclear attack warnings, which led quickly to studies and investigations as to the cause, which turned out to be faulty computer chips.

The 427M program was a set of largely disjointed "stovepipe" projects, which were combined later into the next major upgrade, which became known as the Cheyenne Mountain Upgrade Program. This program came to include a variety of backup systems, both electronic and physical. The USAF developed backup facilities at Offutt AFB near Omaha, Nebraska (the home of Strategic Air Command), and at Peterson AFB in Colorado Springs, along with an existing NORAD backup facility at Malmstrom AFB near Great Falls, Montana. The various upgrades, like their predecessors, ran into cost overruns and schedule slips that accompanied their technical problems. Again came a variety of investigations, which again pointed to problems with systems integration of the many sensors, computers, and facilities. The Cheyenne Mountain Upgrade program finally reached full operational capability (FOC) in October 1998.

In the 1991 Gulf War, Defense Support Program data on Iraqi ballistic missile launches fed into NORAD and then to military units in the Gulf. From that time forward, the military has taken a variety of measures to improve speed and accuracy of ballistic missile and other data from "strategic" sources such as NORAD to tactical units in wartime. By the early 21st century, another series of upgrades were under way, this time to take advantage of technical improvements in computer workstations and computer networks such as the Internet and World Wide Web.

Information from NORAD feeds into the highest level political and military authorities so as to determine, in the worst case, whether a nuclear counterstrike should be launched or whether any other measures are required. With the advent of ballistic missiles, the time available for the nuclear "go code" decision from detection of the ballistic missiles from space and from ground-based radar shrank from hours down to 15 to 30 minutes. Furthermore, hydrogen bombs in space or the upper atmosphere would disrupt the ionosphere, thereby disrupting most long-range radio communications, and destroy ground-based wire communication systems near nuclear impact points. One space-based solution to this problem in the 1960s and 1970s was the creation of the Emergency Rocket Communications System, which would launch Blue Scout (1963–1967) or Minuteman (after 1967) rockets from Wallops Island, Virginia, to high altitude, from where it would send an Emergency Action Message such as the nuclear go-code by radio, thus bypassing ionospheric disruptions. In the 1980s, the Reagan administration approved creation of the Milstar satellite communications system, which was nuclear-hardened so as to send the Emergency Action Message to American nuclear forces around the world during a nuclear war. The end of the Cold War reduced, but did not eliminate, threats to the U.S. command and control system.

The Soviet Union faced similar problems, compounded by the political control of nuclear weapons by the Soviet secret police, the KGB. By the late 1960s, the Soviets created the Signal system, which could detect an attempt by a crew to perform an unauthorized ballistic missile launch. In the 1970s, the Molniya satellite communications system enhanced Soviet command and control, although these satellites were vulnerable to nuclear attack in space. By the 1980s, the Soviets created an automatic nuclear response system known as Perimetr, much like the hypothetical "doomsday machine" satirized in the early 1960s film *Dr. Strangelove*. This system, deployed in 1985, would automatically authorize nuclear retaliation even if the national authorities were dead. The Soviets also developed their own ballistic-missile-based communications system like the American Emergency Rocket Communications System.

There are two recent works on satellite mission control systems. Mudgway's *Uplink-Downlink* describes the evolution of Jet Propulsion Laboratory's Deep Space Network.[132] This is almost entirely a civilian story, but the military

132. Douglas J. Mudgway, *Uplink-Downlink: A History of the Deep Space Network, 1957–1997* (Washington, DC: NASA SP-2001-4227, 2001).

origins of the program are detailed in chapter 2. Arnold's *Spying from Space* is the first major published study of a military satellite control system, the Air Force Satellite Control Facility.[133] Spires's *Beyond Horizons* also has discussions of satellite control in the USAF among its many other topics.[134]

The SAGE system has a small but significant literature in the history of computing. The foremost reference is Redmond and Smith's tome, *From Whirlwind to MITRE*.[135] Jacobs's *The SAGE Air Defense System* gives an anecdotal account of SAGE's development.[136] Edwards's eclectic *The Closed World* put SAGE into a broader Cold War context through a postmodern discourse analysis.[137] In 1983, the *Annals of the History of Computing* published a SAGE special issue that included a collection of articles on various facets of the computer system.[138] Two institutional histories link SAGE to broader issues in command and control: MITRE Corporation's corporate history and Baum's history of System Development Corporation.[139] Hughes's *Rescuing Prometheus* also has a chapter on SAGE.[140] Dyer and Dennis produced a new history of MITRE in 1998.[141]

Larger scale command and control systems and their ties to the national command authorities, such as NORAD and WWMCCS, have a surprisingly limited literature, given the importance of the subject for the survival of the United States in wartime. An early external description of NORAD is in DeVere and Johnson.[142] Chapman provides a full history of NORAD's Cheyenne Mountain Complex up to 1989 in *Legacy of Peace*.[143] The history of WWMCCS is told in Pearson, *The World Wide Military Command and Control System*.[144] Control of British and North Atlantic Treaty Organization (NATO) nuclear forces to the mid-1960s is discussed in Twigge and Scott's *Planning*

133. David Christopher Arnold, *Spying from Space: Constructing America's Satellite Command and Control Systems* (College Station: Texas A&M Press University, 2005).

134. Spires, *Beyond Horizons*.

135. Kent C. Redmond and Thomas A. Smith, *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* (Cambridge, MA: MIT Press, 2000).

136. John F. Jacobs, *The SAGE Air Defense System: A Personal History* (Bedford, MA: MITRE Corporation, 1986).

137. Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996).

138. *Annals of the History of Computing* 5, no. 4 (October 1983).

139. *MITRE: The First Twenty Years* (Bedford, MA: MITRE Corporation, 1979); Claude Baum, *The System Builders: The Story of SDC* (Santa Monica, CA: System Development Corporation, 1981).

140. Thomas P. Hughes, *Rescuing Prometheus* (New York: Pantheon Books, 1998), chap. 2.

141. Davis Dyer and Michael Aaron Dennis, *Architects of Information Advantage: The MITRE Corporation Since 1958* (Montgomery, AL: Community Communications, 1998).

142. G. T. DeVere and N. L. Johnson, "The NORAD Space Network," *Spaceflight* 27, nos. 7–8 (1985): 306–309.

143. Richard G. Chapman, Jr., *Legacy of Peace: Mountain with a Mission, NORAD's Cheyenne Mountain Combat Operations Center, The Cold War Years: 1946–1989* (Colorado Springs, CO: Mountain Express Printing, 1989).

144. David E. Pearson, *The World Wide Military Command and Control System: Evolution and Effectiveness* (Maxwell AFB, AL: Air University Press, 2000).

Armageddon.[145] Blair's *Strategic Command and Control* from 1985 remains a valuable source on the overall control of nuclear forces,[146] as is Bracken's 1983 *Command and Control of Nuclear Forces*.[147] For the Soviet Union and Russia, Zaloga's *The Kremlin's Nuclear Sword* is the best introduction, with information on Signal, Perimetr, etc.[148]

Communications

Separate from the issue of warfare are everyday military communications for logistics, as well as tactical communications for conventional force operations. The United States has particular need for worldwide communications due to the distribution of American military forces around the globe during and after the Cold War. The first communications satellite experiment was Project SCORE (Signal Communication by Orbiting Relay Equipment), which used a modified Atlas ICBM to broadcast a taped message from President Eisenhower in 1958. The Army Signal Corps launched the first repeater satellite, Courier, in 1960, while working on a more sophisticated satellite known as Advent. Advent was too ambitious and was canceled in 1962, but in 1964, the Department of Defense created the Initial Defense Communications Satellite Program (IDCSP), managed by the Defense Communications Agency. The Air Force built the satellites, while the Army Satellite Communications Agency handled the ground segment. IDCSP consisted of a constellation of simple Philco satellites in medium-Earth orbit, the first seven of which were launched in 1966. The military, from that time to the present, also leased transponders on commercial communications satellites for less sensitive logistical and other information.

The second generation of military satellites was known as the Defense Satellite Communications System II, or DSCS (pronounced "discus") II. Built by TRW, the first pair of these much more capable satellites were launched in 1971. Whereas IDCSP satellites could each handle 11 tactical-quality voice circuits, DSCS II satellites each had capacity for 1,300 voice channels and could communicate with much smaller antennas on the ground. DSCS III satellites, built by General Electric and first launched in 1982, were even more capable, with antijamming capabilities and spot beams. DSCS III satellites continue to operate into the 21st century.

145. Stephen Twigge and Len Scott, *Planning Armageddon: Britain, the United States and the Command of Western Nuclear Forces, 1945–1964* (Amsterdam: Harwood Academic Publishers, 2000).

146. Bruce G. Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (Washington, DC: Brookings Institution Press, 1985).

147. Paul Bracken, *The Command and Control of Nuclear Forces* (New Haven, CT: Yale University Press, 1983).

148. Zaloga, *The Kremlin's Nuclear Sword*.

In the meantime, the Navy wanted its own system for mobile fleet communications. The Lincoln Laboratory of MIT, with funding from all of the services, created a series of experimental satellites to test a variety of frequency ranges and capabilities. The first military satellites operated in Super High Frequency (SHF), which required very large ground antennas. Mobile communications required smaller ground antennas, often using Ultra-High Frequencies (UHF). Lincoln Experimental Satellites 3-6 tested these capabilities, leading to the Hughes-built Tacsat, which conclusively proved the utility of UHF communications for the U.S. Navy in particular. The Navy then funded development of the Fleet Satellite Communications (FLTSATCOM) system in the 1970s, but development delays led to purchase of the so-called "Gapfiller" satellites, also built by Hughes. Gapfiller and FLTSATCOM were both used in 1980s, with two FLTSATCOM satellites, controlled from Point Mugu, California, remaining in operation as of February 2005.

The USAF originally developed the Milstar communications satellites in the 1980s for low-rate, nuclear-hardened communications capabilities to ensure the nuclear "go-code" could be sent in nuclear war. When the Cold War ended, the remaining Milstar satellites were modified for higher-rate communication capabilities for tactical purposes. Since the 1970s, the increasing use of imagery for strategic and tactical purposes has driven the development of satellite communication capabilities towards ever greater speeds. The KH-11 reconnaissance satellites, which were the first to use radio signals to send imagery, required communications satellites such as the Satellite Data System to relay the data. Later systems, such as the Lacrosse radar-based reconnaissance satellite, used the Tracking and Data Relay Satellite System also used by NASA. The Ultra-High Frequency Follow-On system, first launched in 1993, is the replacement for the aging FLTSATCOM design. With ever greater demand for communications bandwidth largely driven by sending digital imagery, the U.S. military began leasing significant amounts of time and transponders from commercial carriers, including its 2000 deal with Iridium Satellite LLC to lease the Iridium global satellite constellation that had gone bankrupt.

The Soviet Union likewise developed military communications systems, starting with the well-known Molniya satellites in 1965. Because of the far northern latitudes of the Soviet Union, the Soviets have predominantly used medium-Earth-orbit systems to ensure coverage over the Poles. Later, the Soviets combined communications with navigational capabilities with the Tsiklon (first launched 1967) and later Tsiklon M system (first launched 1974). The Kristal and Strela satellite constellations were also developed, along with the geosynchronous Raduga communications system.

Military satellite communications have also been crucial to other countries, starting with the United Kingdom for the Royal Navy, which developed and operated its Skynet system starting in 1969, and to NATO, which since the 1970s has had its own series of satellites. China developed its Dong Fang Hong communications satellites starting in 1984. Many other countries have military satellite communication capabilities through their own domestic communications satellites. These satellites are generally mixed military-civilian systems.

No comprehensive history of satellite communications, or of military satellite communications, exists. However, some historical research has begun. The origin of satellite communications is best told in Whalen's *The Origins of Satellite Communications*, including the relationships between the military, NASA, and industry in its formative period in the 1950s and early 1960s.[149] Butrica's edited *Beyond the Ionosphere* contains a collection of historical papers on a variety of communications satellite topics, including military efforts of the USAF, Navy, and MIT's Lincoln Laboratories.[150] Martin's *Communication Satellites*, now in its fourth edition, is an essential reference, providing a brief overview of all communications satellites up to its publication date, including source information on where to get further data.[151] Spires and Sturdevant provide an overview of USAF military satellite communications, which is reproduced in *Beyond the Ionosphere*.[152] Van Trees et al. provide an overview of satellite communications in a 2004 article.[153] Lee's *History of the Defense Satellite Communications System* is one of the few works devoted exclusively to military space communications.[154] Davis described Project SCORE in a 1999 article.[155] Richelson describes the Satellite Data System (SDS) in a 1982 article in the *Journal of the British Interplanetary Society*.[156] Day's 1999 *Spaceflight* article discusses SDS and its three launches from the Space Shuttle.[157] The U.S. and Soviet navies' use of communications satellites is well told in Friedman's

149. David J. Whalen, *The Origins of Satellite Communications, 1945–1965* (Washington, DC: Smithsonian Institution Press, 2002).

150. Andrew J. Butrica, ed., *Beyond the Ionosphere: Fifty Years of Satellite Communications* (Washington, DC: NASA SP-4217, 1997).

151. Donald H. Martin, *Communications Satellites*, 4th ed. (Reston, VA: AIAA, 2000).

152. David N. Spires and Rick W. Sturdevant, "From Advent to Milstar: The U.S. Air Force and the Challenges of Military Satellite Communications," *Journal of the British Interplanetary Society* 50, no. 6 (1997): 207–214.

153. Harry L. Van Trees, Harry D. Raduege, Rick W. Sturdevant, and Ronald E. Thompson, "Military Satellite Communications: From Concept to Reality," in *The Limitless Sky: Air Force Science and Technology Contributions to the Nation*, ed. Alexander H. Levis (Washington, DC: Air Force History and Museums Program, 2004), pp. 175–209.

154. Major Robert E. Lee, *History of the Defense Satellite Communications System (1964–1986)*, Air Command and Staff College Report No. 87-1545 (Maxwell AFB, AL: Air University Press, 1987).

155. Deane Davis, "The Talking Satellite: A Reminiscence of Project SCORE," *Journal of the British Interplanetary Society* 52 (1999): 239–258.

156. Jeffrey Richelson, "The Satellite Data System," *Journal of the British Interplanetary Society* 37, no. 5 (1984): 226–228.

157. Dwayne A. Day, "Out of the Shadows: The Shuttle's Secret Payloads," *Spaceflight* 41, no. 2 (February 1999): 78–84.

Seapower and Space.[158] Getting describes early military communications programs in his autobiography.[159] Recent issues and options for leasing commercial systems are discussed in a RAND study by Bonds et al.[160]

Harvey's *Russia in Space* has an overview of Soviet and Russian communications systems.[161] Hendrickx describes the early Molniya program.[162] The Chinese program, including its communications satellites, is discussed in Clark's overview in the *Journal of the British Interplanetary Society*.[163] Harvey also gives some attention to the Dong Fang Hong satellites in his *The Chinese Space Programme*.[164] Harris describes the British Skynet program.[165]

BALLISTIC MISSILE DEFENSE

Unlike most other areas of military space, defense against intercontinental ballistic missiles (ICBMs) is a subject that has spawned great public interest in the United States, with high-profile political debates highlighting the subject from its inception in the 1960s, and particularly in the mid-1980s with the initiation of Ronald Reagan's Strategic Defense Initiative (SDI), which critics called "Star Wars" after the 1977 film of that name. In turn, these political debates have led to a minor industry of polemical works both for and against ballistic missile defense and its alleged impact on international political and military stability. Amazingly, despite the thousands of pages and dozens of works on the subject, there is no comprehensive history of the actual ballistic missile defense systems and programs. In fact, there are no comprehensive public histories of *any* of the ballistic missile defense systems that have actually been deployed, the SDI program itself, or its Soviet counterparts.

From the moment that Nazi Germany began firing V-2s at London, British and American soldiers, scientists, and engineers began searching for ways to counter these apparently unstoppable weapons. During World War II, the only counter was to attack launch sites and logistics for the V-2. Once in flight, there was nothing that could stop them, due to their extremely high speed. After

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158. Norman Friedman, *Seapower and Space: From the Dawn of the Missile Age to Net-Centric Warfare* (Annapolis, MD: Naval Institute Press, 2000).

159. Ivan A. Getting, *All in a Lifetime: Science in the Defense of Democracy* (New York: Vantage Press, 1989).

160. Tim Bonds, Michale G. Mattock, Thomas Hamilton, Carl Rhodes, Michael Scheiern, Philip M. Feldman, David R. Frelinger, and Robert Uy, *Employing Commercial Satellite Communications: Wideband Investment Options for the Department of Defense* (Santa Monica, CA: RAND, 2000).

161. Harvey, *Russia in Space: The Failed Frontier?*

162. Bart Hendrickx, "The Early Years of the Molniya Program," *Quest: The History of Spaceflight Quarterly* 6, no. 3 (1998): 28–36.

163. Phillip Clark, "Review of the Chinese Space Programme," *Journal of the British Interplanetary Society* 52 no. 9/10 (1999): 350–376.

164. Harvey, *The Chinese Space Programme: From Conception to Future Capabilities.*

165. R. L. "Dick" Harris, "Military Satellite Communication in the UK," *Spaceflight* 37, no. 10 (1995): 348–352.

the war, the U.S. Army developed its Nike-Ajax surface-to-air missiles, and the Army Air Forces contracted Project THUMPER with General Electric and the University of Michigan for Project WIZARD to investigate using missiles to destroy incoming ballistic missiles. In 1955, the Army contracted with Western Electric to create an antiballistic missile system, which led ultimately to the Nike-Zeus antiballistic missile. In 1958, the Air Force's Project WIZARD was reduced to research on radar and command and control, and the Army gained control of the antiballistic missile program. The Advanced Research Projects Agency (ARPA) developed an idea in July 1960 for a space-based system called Ballistic Missile Boost Intercept, or BAMBI. Nike-Zeus successfully intercepted an Atlas ICBM in 1962 but remained in research and development. Instead, the system's capabilities were developed further to the Nike-X, which used an upgraded Nike-Zeus missile known as Spartan.

In 1967, President Lyndon Johnson approved development and deployment of the SENTINEL system, which was to be a national ballistic missile defense system with 18 missile sites. However, with the growth of the antiwar movement resulting from the Vietnam War, support for SENTINEL shrank, and it was scaled back to the smaller SAFEGUARD system, which was barely approved in 1969. Congress funded only 2 of the 12 proposed sites, which soon shrank to only 1 site north of Grand Forks, North Dakota, to protect a Minuteman ICBM field. President Richard Nixon used the antiballistic missile (ABM) system as a bargaining chip with the Soviet Union, leading to the signing of the ABM Treaty in 1972, which with a further protocol in 1974 allowed the United States and Soviet Union one missile site each. The system itself, which used new phased-array radars, deployed the long-range Spartan and the short-range Sprint missiles, each tipped with nuclear warheads. In September 1975, the system became fully operational, but the next month, Congress terminated its funding. The next year, the Army began deactivation, and by 1977, the site was in "caretaker status," with only its Perimeter Acquisition Radar remaining functional.

The Soviet Union also began development of its own ABM systems in the late 1950s. Initial testing occurred at Sary Shagan in 1956 and led to the creation of the Anti-Missile Defense Forces in 1958. The first successful ballistic missile interception occurred in 1960, with the actual destruction of a test missile in 1961 using conventional explosives. Nuclear testing followed shortly thereafter. After an abortive attempt to deploy a system around Leningrad in the early 1960s, the Soviets deployed their first system, the A-35, around Moscow beginning in 1967. A series of upgrades followed both with the radar and missile systems. The upgraded system, the A-135, became fully operational only in the mid-1990s, with its new missiles, the SH-08 Gazelle and the SH-11 Gorgon, functioning like the American Sprint and Spartan for a layered defense. Thus the Soviet Union, unlike the United States, has kept an operational ABM system in place continuously since the late 1960s.

Even though the United States dismantled its ABM system in the mid-1970s, research and development continued on the relevant technologies. A revival came in March 1983 when President Ronald Reagan announced the Strategic Defense Initiative. After his landslide reelection in 1984, Reagan pushed major funding increases for strategic defense and created the Strategic Defense Initiative Organization (SDIO). SDIO investigated a variety of approaches to ballistic missile defense, including space-based lasers and kinetic kill vehicles, along with a variety of Earth-based approaches. With the end of the Reagan administration, SDI did not die, but it was scaled back, refocused on research, and renamed several times. The possibility of antiballistic missile systems got a boost during the Gulf War of 1991 when Patriot batteries intercepted some Iraqi Scud missiles over Israel and Saudi Arabia. When Pakistan and Iran tested medium-range ballistic missiles in 1998 and North Korea attempted to put a satellite in orbit, the debate over ABM systems heated up again. Accelerated development followed but did not lead to a deployed system, partly due to technical issues. Through 2004, testing of ABM technologies continued with mixed success.

Chun's 2003 articles in *Quest* are a good starting point for the history of Nike-Zeus.[166] These articles rely on the Army's *Missiles Handbook*, published annually in the late 1950s and early 1960s.[167] Lonnquest and Winkler's *Defend and Deter* provides an overview of Cold War missile systems, including Nike-Zeus and SAFEGUARD.[168] Bowen's 2005 *Quest* article provides a short overview of SAFEGUARD,[169] drawing significantly from three internal Army sources.[170] Walker et al. provide a historical site assessment.[171] Bruce-Briggs provides an overview of ABM systems through the early SDI program.[172]

166. Clayton K. S. Chun, "Defending Against Hitler's Vengeance: The U.S. Army and the V-2," *Quest: The History of Spaceflight Quarterly* 10, no. 2 (2003): 45–52; Clayton K. S. Chun, "Nike-Zeus' Thunder and Lightning: From Antiballistic Missile to Antisatellite Interceptor," *Quest: The History of Spaceflight Quarterly* 10, no. 4 (2003): 40–47.

167. *Office Directorate of Progress and Statistical Reporting U.S. Army Missiles Handbook* (U) (Washington, DC: Department of the Army, 1959–61). These documents, from 1959 to 1961, have been declassified.

168. John C. Lonnquest and David F. Winkler, *To Defend and Deter*, USACERL Special Report 97/01 (Champaign, IL: U.S. Army Construction Engineering Research Laboratories, 1996).

169. Gregory S. Bowen, "SAFEGUARD: North Dakota's Front Line in the Cold War," *Quest: The History of Spaceflight Quarterly* 12, no. 1 (2005): 38–50.

170. Bell Laboratories, *ABM Project History* (Whippany, NJ: U.S. Army Ballistic Missile Defense Command, 1975); James H. Kitchens III, *A History of the Huntsville Division: US Army Corps of Engineers: 1967–1976* (Huntsville, AL: U.S. Army Corps of Engineers, 1978); James A. Walker, Frances Martin, and Sharon S. Watkins, *Strategic Defense: Four Decades of Progress* (Washington, DC: Historical Office, U.S. Army Space and Strategic Defense Command, 1995).

171. James A. Walker et al., compilers, *Historic American Engineering Record Documentation for the Stanley R. Mickelson Safeguard Complex*, vol. 1, *Historical Context*, and vol. 2, *Architectural Data & Photographs*, HAER #ND-9 (Huntsville, AL: U.S. Army Space and Strategic Defense Command, September 1996).

172. B. Bruce-Briggs, *The Shield of Faith* (New York: Simon & Schuster, 1988).

The history of the Soviet Union's ABM systems are described in Zaloga's *The Kremlin's Nuclear Sword*, and also in Whitmore's *Quest* articles in 2002–2003.[173] Mathers discusses Soviet ballistic missile defense (BMD) during the Khrushchev era.[174] The Federation of American Scientists also provides good material on Soviet ABM systems.[175] Siddiqi's 1998 *Spaceflight* article describes the Soviet ground- and space-based laser programs FON and Polyus.[176] Newhouse's *Cold Dawn* is the classic introduction to the history of SALT negotiations.[177] Hays provides a good overview of the Strategic Arms Reduction Treaties (START I and START II).[178]

The best starting point to understand SDI's beginnings is Baucom's *The Origins of SDI*.[179] Baucom also provides an overview of SDI's organization, as does Mary FitzGerald.[180] To date, there are no published overview technical histories of SDI and its descendants. However, Frances Fitzgerald provides an overview of SDI politics during the Reagan administration, and Graham does the same for the later Clinton and early G. W. Bush administrations.[181] Simmons and Bythrow describe Delta Star, an SDI Organization experiment to track launchers from space.[182] Lagrasse and Farmin narrate the TSX-5 experiment for the Ballistic Missile Defense Organization.[183]

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173. Zaloga, *The Kremlin's Nuclear Sword*; Paul Whitmore, "Red Bear on the Prowl: Space-related Strategic Defense in the Soviet Union, Part I," *Quest: The History of Spaceflight Quarterly* 9, no. 4 (2002): 22–30.

174. Jennifer G. Mathers, "A Fly in Outer Space: Soviet Ballistic Missile Defence During the Khrushchev Period," *Journal of Strategic Studies* 21, no. 2 (1998): 31–59.

175. A. Karpenko, "ABM and Space Defense," Federation of American Scientists Web site, 1999, *http://www.fas.org/spp/starwars/program/soviet/990600-bmd-rus.htm*.

176. Asif A. Siddiqi, "Cold War in Space: A Look Back at the Soviet Union," *Spaceflight* 40, no. 2 (February 1998): 63–68.

177. John Newhouse, *Cold Dawn: The Story of SALT* (New York: Holt, Rinehart, and Winston, 1973).

178. Peter L. Hays, *United States Military Space: Into the Twenty-First Century*, INSS Occasional Paper 42 (USAF Academy, CO, and Maxwell AFB, AL: USAF Institute for National Security Studies and Air University Press, 2002).

179. Donald Baucom, *The Origins of SDI, 1944–1983* (Lawrence: University Press of Kansas, 1993).

180. Donald R. Baucom, "Developing a Management Structure for the Strategic Defense Initiative," in *Organizing for the Use of Space: Historical Perspectives on a Persistent Issue*, ed. Roger D. Launius, vol. 18 (San Diego, CA: Univelt, 1995), pp. 187–215; Mary C. FitzGerald, *The New Revolution in Russian Military Affairs*, Whitehall paper series, no. 26 (London: Royal United Services Institute for Defence Studies, 1994).

181. Frances Fitzgerald, *Way Out There in the Blue: Reagan, Star Wars and the End of the Cold War* (New York: Touchstone Books, 2001); Bradley Graham, *Hit to Kill: The New Battle Over Shielding America from Missile Attack* (New York: PublicAffairs, 2001).

182. Frederick Simmons and Peter Bythrow, "Delta Star: an SDIO Space Experiment," *Crosslink* 2, no. 2 (summer 2001): 23–29.

183. Michael L. La Grassa and James R. Farmin, "TSX-5: Another Step Forward for Space-Based Research," *Crosslink* 2, no. 2 (summer 2001): 30–37.

Space Intelligence and Reconnaissance

Using space systems to divine the intentions and capabilities of other nations is a crucial aspect of military space, with a significant and growing historical literature. The use of satellites for reconnaissance was presented in RAND's initial study of artificial satellites in 1946. The U.S. government was desperate for information about secretive Soviet efforts, particularly with respect to nuclear and ballistic missile capabilities. In the 1950s, the United States, with cooperation from Great Britain and others, used a variety of means to gather both photographic and electronic intelligence information, including balloon and aircraft overflights. These culminated with the U-2 program, which had its first mission over the Soviet Union in 1956. American officials realized that sooner or later, the Soviets would develop an antiaircraft missile that could shoot down U-2s, an event that transpired in 1960. In the meantime, the United States began development of a satellite that could replace the U-2. Reconnaissance satellites became a top priority of the military and intelligence communities at this time and have remained so to the present day. A major priority for the Eisenhower and Kennedy administrations was the establishment of the principle of "freedom of space," so as to allow American reconnaissance satellites to gather intelligence of the Communist bloc.

The U.S. reconnaissance satellite effort began as the USAF's Project WS-117L in the mid-1950s. It led to the CORONA and Samos programs for reconnaissance and MIDAS for early warning. The USAF-funded Samos program intended to provide real-time intelligence data by sending images from on-board film readout to the ground by radio. Unfortunately, the technology to acquire high-resolution digital imagery was not yet mature, and after 11 test flights with mixed results, the program was canceled. In the meantime, the CIA, with the Eisenhower administration's encouragement, developed the CORONA film-return system. Under the public name of Discoverer, which was proclaimed to launch life science and engineering technology experiments, the CIA began test flights. After 12 consecutive failures, in August 1960 the first CORONA capsule returned successfully from space. The next flight, Discoverer 14, put a camera in orbit and photographed more of the Soviet Union than all previous air overflights combined.

The CORONA program operated until 1972, by which time it orbited a variety of cameras, improving ground resolution from about 40 feet to 6 feet. Various CORONA missions also incorporated stereo cameras, two film buckets to increase mission length, and mapping cameras for military targeting. Some also carried subsatellites that separated from the main satellite once in orbit, generally for electronics and signals intelligence gathering. Shortly after the first successful flight in 1960, the Eisenhower and Kennedy administrations created, in secret, the National Reconnaissance Office (NRO) to manage CORONA and other space intelligence assets. To handle the massive flow of imagery, the U.S. government created the National Photographic Interpretation Center.

CORONA and its successors were crucial to maintaining peace during the Cold War, as first the U.S. and shortly thereafter the Soviet Union monitored each other's nuclear capabilities. This mutual ability and its high value to each side made it possible to sign treaties banning weapons of mass destruction from space, to limit ballistic missile defenses, and to allow the signing of verifiable arms control treaties starting in the 1970s. CORONA proved in the early 1960s that American fears that the Soviets were ahead in the development and deployment of ICBMs were unfounded. In fact, the "missile gap" was massively in favor of the United States. This information allowed the Kennedy and later administrations to scale back nuclear missile deployments and to stand firm against Soviet threats.

A variety of successor systems for optical reconnaissance followed CORONA, starting with the KH-9 Hexagon in the early 1970s and the KH-11 Kennan real-time optical reconnaissance system. While the KH-9 provided higher resolution using film-return methods, the KH-11 fulfilled the USAF's dream of a real-time optical reconnaissance system, which allowed much faster return of data than the slow film-bucket capability. In parallel, the United States also developed a variety of signals and electronic intelligence systems, under a variety of code names such as Rhyolite, Canyon, and Magnum, and eventually an active radar-imaging satellite known as Lacrosse that allowed spy satellites to "see" through clouds and at night. The Advanced KH-11, Lacrosse, and a variety of signals and electronics intelligence satellites continue to operate today.

The Soviet Union initially objected to U.S. reconnaissance systems, but only until it orbited its own systems, at which point Soviet leaders quietly dropped their objections to these highly useful devices. Korolev's OKB-1 developed the first Soviet reconnaissance system, known as Zenit, from the Vostok capsule used to orbit humans, by replacing the human gear with camera systems. Like the United States, the Soviets then developed a variety of improved optical systems, along with their own electronics and signals intelligence satellites. Improved optical satellites, under the name Yantar, first flew in 1974, with the real-time digital Yantar Terilen system first flying in 1982. New systems, known as Orlets and Arkon, are also currently flying.

China, France, Israel, and Japan have also developed space photoreconnaissance capabilities. China's Fanhui Shi Yao Gang Weixing satellites, first successfully launched in 1975, are recoverable optical imaging satellites, probably at least in part for military purposes. France, Italy, and Spain collaborated to develop the Helios reconnaissance satellites, first launched in 1995. A second Helios was launched in 1999, and the second-generation Helios 2A was placed in orbit in December 2004. Israel's Ofeq series of military imaging satellites, first launched in 1988, are now up to Ofeq-5. Japan launched its first pair of Information Gathering Satellites in March 2003 in response to North Korea's attempt to put a satellite in orbit with its Taepodong rocket launch in 1998. A variety of other systems are in development in a number of nations.

The 1990s saw a boom in histories of space intelligence, mainly due to the declassifications and the opening of some former Soviet archives. The NRO's existence was revealed in 1992, in the first Bush administration.[184] In May 1995, a public conference heralded the declassification of CORONA materials, while in August 2002, the National Imagery and Mapping Agency declassified imagery from the KH-7 and KH-9 Mapping Camera.[185] Prior to 1992, Cold War–era attempts to tell the story of space reconnaissance and intelligence systems were necessarily based on many obscure clues with little direct hard evidence. Klass, Kenden, Borrowman, Richelson, Peebles, and Burrows each attempted this prodigious task, with varying degrees of success.[186] Their efforts for CORONA are now outdated but remain valuable for electronics intelligence (ELINT) and signals intelligence (SIGINT) and for optical reconnaissance after CORONA. For signals intelligence, Bamford's recent book on the National Security Agency is a good place to start, although it focuses mainly on nonsatellite programs.[187] McDowell gives an overview of U.S. spy satellite programs, with each satellite's launch date.[188] While significant progress has been made to untangle these programs, many issues and facts will no doubt remain unresolved for decades to come until the relevant sources are declassified.

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184. Bill Gertz, "The Secret Mission of the NRO," *Air Force Magazine* 76 (June 1993): 60–63.

185. Dwayne A. Day, "US Government Declassifies Reconnaissance Satellites Information," *Spaceflight* 45, no. 3 (2003): 116–117.

186. Philip J. Klass, *Secret Sentries in Space* (New York: Random House, 1971); Anthony Kenden, "U.S. Reconnaissance Satellite Programme," *Spaceflight* (July 1978); Anthony Kenden, "Recent Developments in U.S. Reconnaissance Satellite Programmes," *Journal of the British Interplanetary Society* 35, no. 1 (1982): 31–44; Anthony Kenden, "A New Military Space Mission," *Journal of the British Interplanetary Society* 35, no. 10 (1982): 441–444; Gerald L. Borrowman, "Recent Trends in Orbital Reconnaissance," *Spaceflight* 24, no. 1 (1982): 10–13; Jeffrey Richelson, *United States Strategic Reconnaissance*, ACIS Working Paper (Los Angeles: Center for International and Strategic Affairs, University of California, Los Angeles, 1983); Jeffrey T. Richelson, *America's Secret Eyes in Space* (New York: Harper & Row, 1990); Curtis Peebles, *Guardians—Secret Reconnaissance Satellites* (Novato, CA: Presidio Press, 1987); William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Berkley Books, 1988).

187. James Bamford, *Body of Secrets: Anatomy of the Ultra-Secret National Security Agency* (New York: Anchor Books, 2001).

188. Jonathan McDowell, "US Reconnaissance Satellite Program Part I: Imaging Satellites," *Quest: The History of Spaceflight Magazine* 4, no. 2 (1995): 22–33; Jonathan McDowell, "U.S. Reconnaissance Satellite Programs Part 2: Beyond Imaging," *Quest: The History of Spaceflight Magazine* 4, no. 4 (1995): 40–45.

In 1995, the rush of works on the CORONA project based on declassified sources started with a public conference whose proceedings resulted in an edited work by Ruffner.[189] That same conference led also to Day et al., *Eye in the Sky*, which provides a number of excellent articles by historians and participants on CORONA.[190] Day also wrote an early, concise overview of CORONA in two *Quest* issues.[191] Day also followed with articles on other articles on various aspects of the CORONA program and its various camera systems,[192] as well as a variety of other reconnaissance and intelligence programs.[193] McDonald also wrote an early work on CORONA.[194] Not surprisingly, those best able to take advantage of the now-opened archives included those who had written on the subjects before. Peebles soon published an overview history of CORONA.[195] Richelson used these new sources, along with others, to publish a work on the Central Intelligence Agency's Directorate of Science and Technology.[196] Burrows's *This New Ocean*, which attempted a comprehen-

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189. Kevin C. Ruffner, ed., *Corona: America's First Satellite Program* (Washington, DC: CIA History Staff, Center for the Study of Intelligence, 1995).

190. Dwayne A. Day, John M. Logsdon, and Brian Latell, eds., *Eye in the Sky: The Story of the Corona Spy Satellites* (Washington, DC: Smithsonian Institution Press, 1998).

191. Dwayne A. Day, "CORONA: America's First Spy Satellite Program," *Quest: The History of Spaceflight Magazine* 4, no. 2 (1995): 4–21; Dwayne A. Day, "CORONA: America's First Spy Satellite Program Part II," *Quest: The History of Spaceflight Magazine* 4, no. 3 (1995): 28–36.

192. Dwayne A. Day, "A Failed Phoenix: The KH-6 LANYARD Reconnaissance Satellite," *Spaceflight* 39, no. 5 (May 1997): 170–174; Dwayne A. Day, "Mapping the Dark Side of the World Part 1: The KH-5 ARGON Geodetic Satellite," *Spaceflight* 40, no. 7 (July 1998): 264–269; Dwayne A. Day, "Mapping the Dark Side of the World—Part 2: Secret Geodetic Programmes after ARGON," *Spaceflight* 40, no. 8 (August 1998): 303–310; Dwayne A. Day, "Falling Star," *Spaceflight* 40, no. 11 (1998): 442–445; Dwayne A. Day, "Lucky Number 13: The First Success of the CORONA Reconnaissance Satellite Program," *Spaceflight* 46, no. 4 (2004): 165–169; Dwayne A. Day, "First Light: The First Reconnaissance Satellite," *Spaceflight* 46, no. 8 (2004): 327–331.

193. Dwayne A. Day, "Recon for the Rising Sun," *Spaceflight* 41, no. 10 (1999): 420–423; Dwayne A. Day, "Medium Metal—The NRO's Smaller Satellites," *Spaceflight* 42, no. 1 (2000): 32–40; Dwayne A. Day, "Early American Ferret and Radar Satellites," *Spaceflight* 43, no. 7 (2001): 288–293; Dwayne A. Day, "Single Orbit Darts and Mercury Eyeballs: Early Unbuilt Strategic Reconnaissance Platforms," *Spaceflight* 43, no. 11 (2001): 468–470; Dwayne A. Day, "The Army–Air Force Space Race," *Spaceflight* 44, no. 7 (2002): 300–306; Dwayne A. Day, "Ferrets of the High Frontier: U.S. Air Force Ferret and Heavy Ferret Satellites of the Cold War," *Spaceflight* 46, no. 2 (2004): 74–81; Dwayne A. Day, "Pushing Iron: On-Orbit Support for Heavy Intelligence Satellites," *Spaceflight* 46, no. 7 (2004): 289–293.

194. Robert A. McDonald, *Corona Between the Sun and the Earth: The First NRO Eye in Space* (Annapolis Junction, MD: American Society for Photogrammetry and Remote Sensing, 1997); Robert A. McDonald, "CORONA: A Success for Space Reconnaissance, a Look into the Cold War, and a Revolution for Intelligence," *Photogrammetric Engineering and Remote Sensing* 51, no. 6 (1995): 689–720.

195. Curtis Peebles, *The CORONA Project: America's First Spy Satellites* (Annapolis, MD: Naval Institute Press, 1997).

196. Jeffrey T. Richelson, *The Wizards of Langley: Inside the CIA's Directorate of Science and Technology* (Boulder, CO: Westview Press, 2001).

sive history of the "First Space Age," used the new CORONA materials as well.[197] Taubman's *Secret Empire* is a more recent take on Eisenhower's support of CORONA and its predecessors.[198] Arnold's *Spying from Space* focuses on the command and control (C2) system set up for CORONA and deals with much of CORONA's early history as a result.[199] Temple's 2004 book *Shades of Grey* is another solid contribution to space reconnaissance history.[200] Day has a series of articles about the Samos program.[201] Hall describes the transfer of its camera technology to NASA's Lunar Orbiter, as does Day.[202]

RAND's part in the development of satellite reconnaissance is described in Davies and Harris, *RAND's Role in the Evolution of Balloon and Satellite Observations Systems and Related U.S. Space Technology.*[203] Peebles wrote about the balloon projects in *The Moby Dick Project.*[204] Hall sets the stage for satellite reconnaissance with a history of aerial overflights of the Soviet bloc.[205] U.S. Air Force Project 117L, which gave rise to CORONA as well as MIDAS, is discussed in Coolbaugh's 1998 article and in Perry's, as well as in Bowen's overviews of the genesis of military space efforts.[206] Other CORONA-related works include McDonald's edited *CORONA: Between the Sun and the Earth*,

197. Burrows, *This New Ocean.*

198. Philip Taubman, *Secret Empire: Eisenhower, the CIA, and the Hidden Story of America's Space Espionage* (New York: Simon & Schuster, 2003).

199. David Christopher Arnold, *Spying From Space: Constructing America's Satellite Command and Control Networks* (College Station: Texas A&M University Press, 2005).

200. L. Parker Temple, *Shades of Grey: National Security and the Evolution of Space Reconnaissance* (Reston, VA: AIAA, 2004).

201. Dwayne A. Day, "A Sheep in Wolf's Clothing: The Samos E-5 Recoverable Satellite—Part One," *Spaceflight* 44, no. 10 (2002): 424–431; Dwayne A. Day, "A Square Peg in a Cone-Shaped Hole: The Samos E-5 Recoverable Satellite—Part Two," *Spaceflight* 45, no. 2 (2003): 71–79; Dwayne A. Day, "From Cameras to Monkeys to Men: The Samos E-5 Recoverable Satellite—Part Three," *Spaceflight* 45, no. 9 (2003): 380–389.

202. R. Cargill Hall, *SAMOS to the Moon: The Clandestine Transfer of Reconnaissance Technology Between Federal Agencies* (Chantilly, VA: NRO History Office, October 2001); Dwayne A. Day, "From Above the Iron Curtain to Around the Moon: Lunar Orbiter and the Samos Spy Satellite," *Spaceflight* 47, no. 2 (2005): 66–71.

203. Merton E. Davies and William R. Harris, *RAND's Role in the Evolution of Balloon and Satellite Observation Systems and Related U.S. Space Technology* (Santa Monica, CA: RAND, 1988).

204. Curtis Peebles, *The Moby Dick Project: Reconnaissance Balloons Over Russia* (Washington, DC: Smithsonian Institution Press, 1991).

205. R. Cargill Hall, "The Truth about Overflights: Military Reconnaissance over Russia before the U-2, One of the Cold War's Best-Kept Secrets," *MHQ: The Quarterly Journal of Military History* 9, no. 3 (1997): 25–39.

206. J. S. Coolbaugh, "Genesis of the USAF's First Satellite Programme," *Journal of the British Interplanetary Society* 51, no. 8 (1998): 283–300; R. L. Perry, *Origins of the USAF Space Program, 1945–1956*, vol. 5, *History of DCAS, 1961*, Air Force Systems Command Historical Publications Series 62-24-10 (Los Angeles, CA: Air Force Systems Command, Space Systems Division, 1961); Lee Bowen, *The Threshold of Space: The Air Force in the National Space Program, 1945–1959* (Wright-Patterson AFB, OH: USAF Historical Division Liaison Office, 1960).

Oder et al.'s *The CORONA Story*, and Lindgren's *Trust but Verify*.[207] There have been concerns about errors in Lindgren's work.[208] Institutional works on the NRO I discuss later in this essay.

The politics of the freedom of space has been the focus of a number of historians. Stephen Ambrose, in his research on Dwight Eisenhower, was among the first to note the importance of the issue in 1981.[209] Rostow analyzed the Open Skies policy one year later.[210] McDougall's . . . *The Heavens and the Earth* provided the first full-length analysis of the issues involved.[211] Hall, with deeper archival research and materials available, revisited the topic in 1995.[212] Day followed with his assessment in 1998.[213] Neufeld revisited the issue in 2000.[214] The most recent assessment is by Bille and Lishock in 2004.[215]

Other relevant materials include McElheny's biography of Eastman Kodak's influential Edwin Land, as well as autobiographies of Richard Bissell and George Kistiakowsky.[216] Ranelagh's overview of the CIA, *The Agency*, contains some information on spy satellite programs.[217] The GRAB SIGINT satellite is described by a 1997 Naval Research Laboratory publication and

207. Robert A. McDonald, ed., *CORONA: Between the Sun and the Earth: The First NRO Reconnaissance Eye in Space* (Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 1997); Frederic C. E. Oder, James C. Fitzpatrick, and Paul E. Worthman, *The CORONA Story* (Washington, DC: National Reconnaissance Office, 1997); David T. Lindgren, *Trust but Verify: Imagery Analysis in the Cold War* (Annapolis, MD: Naval Institute Press, 2000).

208. Dwayne A. Day, "*Trust but Verify: Imagery Analysis in the Cold War*, Review," *Technology and Culture* 42, no. 4 (2001): 822–823.

209. Stephen E. Ambrose, *Ike's Spies: Eisenhower and the Espionage Establishment* (Garden City, NY: Doubleday & Co., 1981).

210. W. W. Rostow, *Open Skies: Eisenhower's Proposal of July 21, 1955* (Austin: University of Texas Press, 1982).

211. McDougall, . . . *The Heavens and the Earth*.

212. R. Cargill Hall, "Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program,* ed. John M. Logsdon, vol. 1, *Organizing for Exploration* (Washington, DC: NASA SP-4218, 1995), pp. 213–229; R. Cargill Hall, "The Eisenhower Administration and the Cold War: Framing American Astronautics to Serve National Security," *Prologue* 27, no. 1 (spring 1995): 59–72.

213. Dwayne A. Day, "A Strategy for Reconnaissance: Dwight D. Eisenhower and Freedom of Space," in *Eye in the Sky*, ed. Day, Logsdon, and Latell, pp. 119–142.

214. Michael J. Neufeld, "Orbiter, Overflight, and the First Satellite: New Light on the Vanguard Decision," in *Reconsidering Sputnik: Forty Years Since the Soviet Satellite*, ed. Roger D. Launius, John M. Logsdon, and Robert W. Smith (Amsterdam: Harwood Academic Publishers, 2000).

215. Matt Bille and Erika Lishock, *The First Space Race: Launching the World's First Satellites* (College Station: Texas A&M Press, 2004), chap. 4.

216. Victor K. McElheny, *Insisting on the Impossible: The Life of Edwin Land, Inventor of Instant Photography* (Reading, MA: Perseus Books, 1998); Richard M. Bissell with Jonathan E. Lewis and Francis T. Pudlo, *Reflections of a Cold Warrior: From Yalta to the Bay of Pigs* (New Haven, CT: Yale University Press, 1996); George Kistiakowsky, *A Scientist at the White House: The Private Diary of President Eisenhower's Special Assistant for Science and Technology* (Cambridge, MA: Harvard University Press, 1976).

217. John Ranelagh, *The Agency: The Rise and Decline of the CIA, from Wild Bill Donovan to William Casey* (New York: Simon & Schuster, 1986).

in Day's "Listening from Above."[218] Ball's *Pine Gap* provides information on U.S. signals intelligence, as do Pike's "CANYON, RHYOLITE, and AQUACADE" and Day's "Ferrets Above."[219] Bamford's 1982 *The Puzzle Palace*, 2002 *Body of Secrets*, and Lindsey's popular book *The Falcon and the Snowman* also provide information on spy satellites, in particular from the Boyce and Lee spy case.[220] An unusual and insightful look at a company's role is found in Lewis's *Spy Capitalism*, which discusses Itek Corporation.[221] Day provided a recent overview of the intelligence space program in 2002.[222]

Non-U.S. reconnaissance systems have significantly less literature. What exists is mostly concerned with the Soviet Union and Russia. Harvey's *Russia in Space* provides an overview.[223] Gorin describes Soviet and Russian optical reconnaissance systems articles in the *Journal of the British Interplanetary Society*, as does Clark.[224] Clark also describes Chinese recoverable satellites, which are probably partly military in nature, in a 1998 *Quest* article.[225] Zorn has a short article on the development of the Israeli satellite intelligence program.[226] A flavor of the interactions between military and civilian systems can be seen in Baker et al., Steinberg, and Dehqanzada and Florini.[227] There are no histories

218. *GRAB: Galactic Radiation and Background* (Washington, DC: Naval Research Laboratory, 1997); Dwayne A. Day, "Listening from Above: The First Signals Intelligence Satellite," *Spaceflight* 41, no. 8 (August 1999): 338–346.

219. Desmond Ball, *Pine Gap: Australia and the U.S. Geostationary Signals Intelligence Satellite Program* (Sydney: Allen & Unwin, 1988); Christopher Anson Pike, "CANYON, RHYOLITE, and AQUACADE," *Spaceflight* 37, no. 11 (November 1995): 381–383; Dwayne A. Day, "Ferrets Above: American Signals Intelligence Satellites During the 1960s," *International Journal of Intelligence and CounterIntelligence* 17, no. 3 (2004): 449–467.

220. James Bamford, *The Puzzle Palace: A Report on NSA, America's Most Secret Agency* (Boston: Houghton Mifflin, 1982); James Bamford, *Body of Secrets: Anatomy of the Ultra-Secret National Security Agency* (New York: Anchor, 2002); Robert Lindsey, *The Falcon and the Snowman: A True Story of Friendship and Espionage* (New York: Simon & Schuster, 1979).

221. Jonathan E. Lewis, *Spy Capitalism: ITEK and the CIA* (New Haven, CT: Yale University Press, 2002).

222. Day, "Intelligence Space Program," pp. 371–388.

223. Harvey, *Russia in Space: The Failed Frontier?*

224. Peter Gorin, "Zenit—the First Soviet Photoreconnaissance Satellite," *Journal of the British Interplanetary Society* 50, no. 11 (1997): 441–448; Peter Gorin, "Black Amber—Russian Yantar-Class Optical Reconnaissance Satellites," *Journal of the British Interplanetary Society* 51 (1998): 309–320; P. S. Clark, "Russian Fifth Generation Photoreconnaissance Satellites," *Journal of the British Interplanetary Society* 52 (1999): 133–150.

225. Phillip S. Clark, "Development of China's Recoverable Satellites," *Quest: The History of Spaceflight Quarterly* 6, no. 2 (1998): 36–43.

226. E. L. Zorn, "Israel's Quest for Satellite Intelligence," *Studies in Intelligence* 10 (winter–spring 2001): 33–38.

227. John C. Baker, Kevin M. O'Connell, and Ray A. Williamson, eds., *Commercial Observation Satellites: At the Leading Edge of Global Transparency* (Santa Monica, CA: RAND and ASPRS, 2001); Gerald M. Steinberg, *Commercial Observation Satellites in the Middle East and Persian Gulf* (Santa Monica, CA: RAND, 2001); Yahya A. Dehqanzada and Ann M. Florini, *Secrets for Sale: How Commercial Satellite Imagery Will Change the World* (Washington, DC: Carnegie Endowment for International Peace, 2000).

yet of European, Japanese, or other military space reconnaissance systems, but some information on these can be found at the Federation of American Scientists Web site[228] and Internet searches of newspapers and blogs.

Finally, an area garnering recent attention is the use of satellite reconnaissance data for a variety of intelligence purposes. This is shown by a recent spate of work on American assessment (largely based on satellite imagery) of the Soviet manned lunar program in the 1960s. The best research on this so far is a two-part series, "The Moon in the Crosshairs," by Day and Siddiqi in 2003 and 2004.[229] Day has followed this with several other articles.[230] Pesavento and Vick have also ventured into this territory, although some of their claims have been challenged.[231]

MILITARY HUMAN SPACEFLIGHT

The American and Soviet military services have been involved with human spaceflight programs from the late 1950s to the present, starting with supplying astronauts and cosmonauts to the fledgling human flight programs, moving on to studies and designs for piloted space reconnaissance and bombing vehicles, and then designing and operating manned military space stations. While most people realize that many astronauts and cosmonauts have been military pilots, few have pondered why the military lent many of its top personnel to civilian spaceflight programs. Even fewer people realize that the U.S. and USSR have had manned military space programs and that the Soviets even operated manned military space stations in the 1970s.

Eugen Sänger developed the idea of a manned space bomber in the 1940s and studied the concept in World War II Nazi Germany. This "Silver Bird" vehicle would drop a bomb on New York, skip off the atmosphere, and return to Germany. Walter Dornberger, who headed the German Army's ballistic missile efforts in World War II, brought the idea to the Bell Aircraft Corporation

228. See *http://www.fas.org*.

229. Dwayne A. Day and Asif Siddiqi, "The Moon in the Crosshairs: CIA Intelligence on the Soviet Manned Lunar Programme, Part 1—Launch Complex J," *Spaceflight* 45, no. 11 (2003): 466–475; Dwayne A. Day and Asif Siddiqi, "The Moon in the Crosshairs: CIA Intelligence on the Soviet Manned Lunar Programme, Part 2—The J Vehicle," *Spaceflight* 46, no. 3 (2004): 10–11, 114–125.

230. Dwayne A. Day, "The Secret of Complex J," *Air Force* 87, no. 7 (July 2004): 72–76; Dwayne A. Day, "In the Shadows of the Moon Race," *Spaceflight* 46, no. 11 (2004): 436–440; Dwayne A. Day, "From the Shadows to the Stars: James Webb's Use of Intelligence Data in the Race to the Moon," *Air Power History* 51, no. 4 (winter 2004).

231. Peter Pesavento and Charles P. Vick, "The Moon Race 'End Game': A New Assessment of Soviet Crewed Lunar Aspirations—Part 1," *Quest: The History of Spaceflight Quarterly* 11, no. 1 (2004): 6–30; Peter Pesavento and Charles P. Vick, "The Moon Race 'End Game': A New Assessment of Soviet Crewed Lunar Aspirations—Part 2," *Quest: The History of Spaceflight Quarterly* 11, no. 2 (2004): 6–57.

in the United States, which in 1952 proposed to study the concept further with USAF funding. The Bell study, along with the USAF's preference for manned bombers over missile systems, resulted in the USAF issuing requirements for a hypersonic strategic bombardment system in 1955. Several feasibility studies were consolidated in October 1957 into the Dyna-Soar program, which would initially design a hypersonic manned research vehicle. By late 1961, with the mass of Dyna-Soar growing and Soviet competition increasing with Gagarin's flight, the USAF dropped suborbital tests and approved the development of the powerful Titan III launcher to put Dyna-Soar into space. However, the success of CORONA and the Soviet Zenit systems ensured that priority for both nations' military space efforts went to reconnaissance satellites. By 1963, each side was willing to tolerate each other's reconnaissance satellites, and threats to this toleration such as potential antisatellite systems like Dyna-Soar were unwelcome. Secretary of Defense Robert McNamara, who was skeptical of its mission, canceled it in December 1963.

However, McNamara agreed that piloted reconnaissance platforms had military potential, so at the same time that he canceled Dyna-Soar, he approved the Manned Orbiting Laboratory (MOL) program to investigate. MOL's immediate lineage included ideas to modify the Gemini capsule—the so-called "Blue Gemini" program—as part of a military space station program called the "Manned Orbital Development System." When the DOD began to consider taking over Gemini, NASA objected vociferously, and the DOD backed down. Ultimately, the USAF decided to modify the Gemini capsule to transport astronauts to the MOL, which would be carried behind the capsule on a Titan III launcher. As MOL's schedule slipped and its cost grew, NASA pushed its Apollo Applications Program (soon to become *Skylab*) and the Vietnam War intensified, increasing pressure to cancel MOL. The success of CORONA and the need for funds to develop its successor robotic reconnaissance craft (the KH-9 Hexagon) led to MOL's cancellation in June 1969.

Human military spaceflight did not end with MOL, as the military considered its participation in NASA's Space Shuttle program. The military's requirements significantly influenced the Shuttle's design, and in the late 1970s, the USAF prepared to fly Shuttle missions by building its own operations center and launch facility, as well as training military astronauts for classified missions. In the 1980s, U.S. military men flew a number of classified missions on the Space Shuttle, the details of which generally remain hidden from the public. One of the missions is known to have deployed two Defense Satellite Communications System III satellites. Others were most likely National Reconnaissance Office missions to deploy various reconnaissance systems. However, the *Challenger* accident of 1986 and the resulting new priorities for the Shuttle soon ended military Shuttle missions.

Similar aspirations for human military missions also spurred the Soviets to develop programs. A "Raketoplan" explored concepts similar to Dyna-Soar. The Soviets also undertook a military space station program. Officially called Salyut, the second, third, and fifth were all Almaz military stations, launched in 1973, 1974, and 1976. Soyuz missions 14, 15, 21, 23, and 24 were all military missions to the *Salyut 3* and *5* stations, performing a variety of military tasks, mostly to determine the value of using cosmonauts for reconnaissance. After these missions, the Soviets concluded that automated satellites were more effective than humans in space, as the humans had limited amounts of time available for observations, as they had to eat, sleep, and maintain the station. This, combined with the much higher costs of human flights, ended human military missions.

Both American and Soviet armed forces also lent military pilots to their respective civilian space programs. From World War II to the early 1960s, military test pilots aimed to go higher and faster, and their efforts, along with the medical experiments, observations, and flight suits made along the way, paved the way for civilian space missions. In the 1950s and 1960s, the relatively high prestige of spaceflight and the potential for human military missions in space made this a reasonable proposition for the armed forces. Before NASA's creation, the military controlled the space program by default. The Army and Air Force competed in early studies and proposals to put humans in space, including the Army's Project Adam and Project Horizon and the Air Force's "Man-In-Space-Soonest," which had one of the worst acronyms possible, MISS.

With NASA's creation, the military's role changed from one of leadership and control to one of support. Over time, as human-piloted missions and crewed space stations faded from military viability in the 1970s and 1980s, the number of military personnel becoming astronauts and cosmonauts has decreased somewhat. The military rationales for the continued movement of military pilots into civilian space programs have become less clear and, to date, have not been investigated by historians. Also, the military continues to support human flight programs with launch range support and a variety of other capabilities. These have declined over time as the civilian programs have frequently developed their own capabilities for astronaut testing, etc.

Myhra describes Sänger's early orbital bomber program in Nazi Germany.[232] Killebrew gives a history of the USAF's efforts to find a role for military men in space.[233] A short history of Dyna-Soar can be found in *Quest* issue 3, num-

232. David Myhra, *Sänger: Germany's Orbital Rocket Bomber in World War II* (Atglen, PA: Schiffer, 2002).

233. Major Timothy D. Killebrew, *Military Man in Space: A History of Air Force Efforts to Find a Manned Space Mission*, Air Command and Staff College Report No. 87-1425 (Maxwell AFB, AL: Air University Press, 1987).

ber 4, which has a number of articles on the program, particularly those by Houchin and by Smith.[234] Houchin's 1997 *Journal of the British Interplanetary Society* article is also insightful.[235] Godwin's recent book on Dyna-Soar is a compilation of original documents.[236] MOL's history is also relatively obscure. Both Peebles[237] and Pealer[238] created three-part series on the project. Houchin's 1995 article investigates the question of NASA's relationship to MOL.[239] Spires's *Beyond Horizons* also describes these programs, along with earlier efforts, such as MISS.[240] Strom provides a brief history of MOL.[241] Jenkins's *Space Shuttle* describes its first hundred missions, a number of which were classified military missions.[242] Day provides an overview of NASA-DOD relations in an overview article in *Exploring the Unknown*.[243] Powell and Day describe military Shuttle missions.[244]

Siddiqi covers the 1960s development of the Soviet Raketoplan and Spiral, along with the 1960s development of Almaz, in *Challenge to Apollo*.[245] He also describes the military Almaz program and consequent Soyuz flights to the military stations in two articles in the *Journal of the British Interplanetary*

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234. Roy F. Houchin II, "Why the Air Force Proposed the Dyna-Soar X-20 Program," *Quest: The History of Spaceflight Magazine* 3, no. 4 (1994): 5–12; Terry Smith, "The Dyna-Soar X-20: A Historical Overview," *Quest: The History of Spaceflight Magazine* 3, no. 4 (1994): 13–18; Roy F. Houchin II, "Why the Dyna-Soar X-20 Program Was Cancelled," *Quest: The History of Spaceflight Magazine* 3, no. 4 (1994): 35–37.

235. Roy F. Houchin II, "Air Force-Office of the Secretary of Defense Rivalry."

236. Robert, Godwin, ed., *Dyna-Soar Hypersonic Strategic Weapons System* (Burlington, Ontario: Apogee, 2003).

237. Curtis Peebles, "The Manned Orbiting Laboratory—Part 1," *Spaceflight* 22, no. 4 (1980): 155–160; Curtis Peebles, "The Manned Orbiting Laboratory—Part 2," *Spaceflight* 22, nos. 7–8 (1980): 270–272; Curtis Peebles, "The Manned Orbiting Laboratory—Part 3," *Spaceflight* 24, no. 6 (1982): 274–277.

238. Donald Pealer, "Manned Orbiting Laboratory (MOL) Part I," *Quest: The History of Spaceflight Magazine* 4, no. 3 (1995): 4–17; Donald Pealer, "Manned Orbiting Laboratory (MOL) Part II," *Quest: The History of Spaceflight Magazine* 4, no. 4 (1995): 28–35; Donald Pealer, "Manned Orbiting Laboratory (MOL) Part 3," *Quest: The Magazine of Spaceflight* 5, no. 2 (1996): 16–23.

239. Roy F. Houchin II, "Interagency Rivalry, NASA, The Air Force, and MOL," *Quest: The History of Spaceflight Quarterly* 4, no. 4 (1995): 36–39.

240. Spires, *Beyond Horizons*.

241. Steven R. Strom, "The Best Laid Plans: A History of the Manned Orbiting Laboratory," *Crosslink* 5, no. 2 (summer 2004): 11–15.

242. Dennis R. Jenkins, *Space Shuttle: The History of the National Space Transportation System: The First 100 Missions* (Stillwater, MN: Voyageur Press, 2001).

243. Dwayne A. Day, "Invitation to Struggle: The History of Civilian-Military Relations in Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civilian Space Program*, ed. John M. Logsdon, vol. 2, *External Relationships* (Washington, DC: NASA SP-4407, 1996), pp. 233–270.

244. Joel W. Powell, "'Secret' Shuttle Payloads Revealed," *Spaceflight* 35, no. 5 (1993): 152–154; Dwayne A. Day, "Secret Shuttle Mission Revealed," *Spaceflight* 40, no. 7 (1998): 256–257.

245. Siddiqi, *Challenge to Apollo*.

Society.[246] Lantratov describes the early Soyuz manned reconnaissance designs.[247] Zimmerman's recent history of space stations also briefly discusses the Soviet military missions.[248] Pesavento[249] describes the Russian shuttle projects, as does Garber.[250]

The military's ballooning experiments at extreme altitudes are described in Ryan's *The Pre-Astronauts*, as well as DeVorkin's *Race to the Stratosphere.*[251] Gantz provides a late-1950s view of USAF astronaut training, and Erickson's dissertation looks at this as one aspect of a larger NASA-DOD relationship.[252] Military involvement with the development of spacesuits is described in Harris's *The Origins and Technology of the Advanced Extra-Vehicular Spacesuit.*[253] Mallan, De Monchaux, and Kozloski also have monographs on the history of spacesuits, including their military origins.[254] There are no published overview histories of military test-pilot training, aerospace medicine, creation of launch facilities and range support, etc. On aerospace medicine, the best source so far is Mackowski's 2002 dissertation.[255] Important early sources include Armstrong's *Aerospace Medicine* and Campbell's *Earthman/Spaceman/*

246. Asif A. Siddiqi, "The Almaz Space Station Complex: A History, 1964–1992, Part 1: 1964–1976," *Journal of the British Interplanetary Society* 52, no. 11/12 (2001): 389–416; Asif A. Siddiqi, "The Almaz Space Station Complex: A History, 1964–1992, Part 2: 1976–1992," *Journal of the British Interplanetary Society* 55, no. 1/2 (2002): 35–67.

247. Konstantin Lantratov, "Soyuz-Based Manned Reconnaissance Spacecraft," trans. Bart Hendrickx, *Quest: The History of Spaceflight Quarterly* 6, no. 1 (1998): 5–21.

248. Robert Zimmerman, *Leaving Earth: Space Stations, Rival Superpowers, and the Quest for Interplanetary Travel* (Washington, DC: Joseph Henry Press, 2003).

249. Peter Pesavento, "Russian Space Shuttle Projects, 1957–1994, Part 1," *Spaceflight* 37, no. 5 (1995): 158–164; Peter Pesavento, "Russian Space Shuttle Projects, 1957–1994, Part 2," *Spaceflight* 37, no. 6 (1995): 192–199; Peter Pesavento, "Russian Space Shuttle Projects, 1957–1994, Part 3," *Spaceflight* 37, no. 7 (1995): 226–233; Peter Pesavento, "Russian Space Shuttle Projects, 1957–1994, Part 4," *Spaceflight* 37, no. 8 (1995): 264–266.

250. Steve Garber, "A Cold Snow Falls: The Soviet Buran Space Shuttle," *Quest: The History of Spaceflight Quarterly* 9, no. 5 (2002): 42–51.

251. Craig Ryan, *The Pre-Astronauts: Manned Ballooning on the Edge of Space* (Annapolis, MD: Naval Institute Press, 1995); David H. DeVorkin, *Race to the Stratosphere: Manned Scientific Ballooning in America* (New York: Springer-Verlag, 1989).

252. Kenneth F. Gantz, ed., *Men in Space: The United States Air Force Program for Developing the Spacecraft Crew* (New York: Duell, 1959); Mark A. Erickson, "The Evolution of the NASA-DoD Relationship from Sputnik to the Lunar Landing" (Ph.D. diss., The George Washington University, 1997).

253. Gary L. Harris, *The Origins and Technology of the Advanced Extra-Vehicular Spacesuit*, AAS History Series, no. 24 (San Diego: Univelt, 2001).

254. Lloyd Mallan, *Suiting Up for Space: The Evolution of the Space Suit* (New York: John Day Company, 1971); Nicholas De Monchaux, *Space Suit* (New York: Springer Verlag, 2002); Lillian D. Kozloski, *U.S. Space Gear: Outfitting the Astronaut* (Washington, DC: Smithsonian Institution Press, 2000).

255. Maura Phillips Mackowski, "Human Factors: Aerospace Medicine and the Origins of Manned Space Flight in the United States" (Ph.D. diss., Arizona State University, 2002).

UNIVERSAL MAN.[256] Early studies of USAF experiments related to human spaceflight can be found in Mallan and Meeter.[257] Information on military astronauts and their training can be found indirectly through numerous astronaut biographies and autobiographies, which I will not list here. Also, Swenson et al.'s early history of Mercury, *This New Ocean*, discusses some of the early military-based astronaut training and selection.[258] Siddiqi's *Challenge to Apollo* describes similar military origins for cosmonauts.[259]

In 1959, Singer discussed the potential of military Moon bases.[260] Springer describes the U.S. Army's Project Adam in a 1994 *Quest* article and the Army's Project Horizon Moon base study in his 1999 "Securing the High Ground."[261] Burrows and Richelson also discuss military Moon base efforts.[262] Stoff describes plans for a military version of the Apollo Lunar Module.[263]

WEATHER AND SCIENCE

The military has funded and developed a variety of experiments and systems to understand space and atmospheric environments and to support space operations. This intersects with literature in the history of science in the development of space science and meteorology. Prior to NASA's existence, space science was almost exclusively funded by the military. The military has had scientific advisers ever since World War II to help guide its technology and scientific programs. The Office of Naval Research became a "proto–National Science Foundation" in the late 1940s and 1950s, funding a variety of research, while the USAF established a Scientific Advisory Board that periodically provided studies and advice, as well as a Chief Scientist's Office to coordinate with academic advisers. The military as a whole used the Research

256. Harry G. Armstrong, *Aerospace Medicine* (Baltimore, MD: Williams & Wilkins, 1961); Paul A. Campbell, *Earthman/Spaceman/UNIVERSAL MAN?* (New York: Pageant Press, 1965).

257. Lloyd Mallan, *Men, Rockets, and Space Rats* (New York: Messner, 1961); George F. Meeter, *The Holloman Story: Eyewitness Accounts of Space Age Research* (Albuquerque: University of New Mexico Press, 1967).

258. Loyd S. Swenson, Jr., James M. Grimwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury* (Washington, DC: NASA SP-4201, 1966).

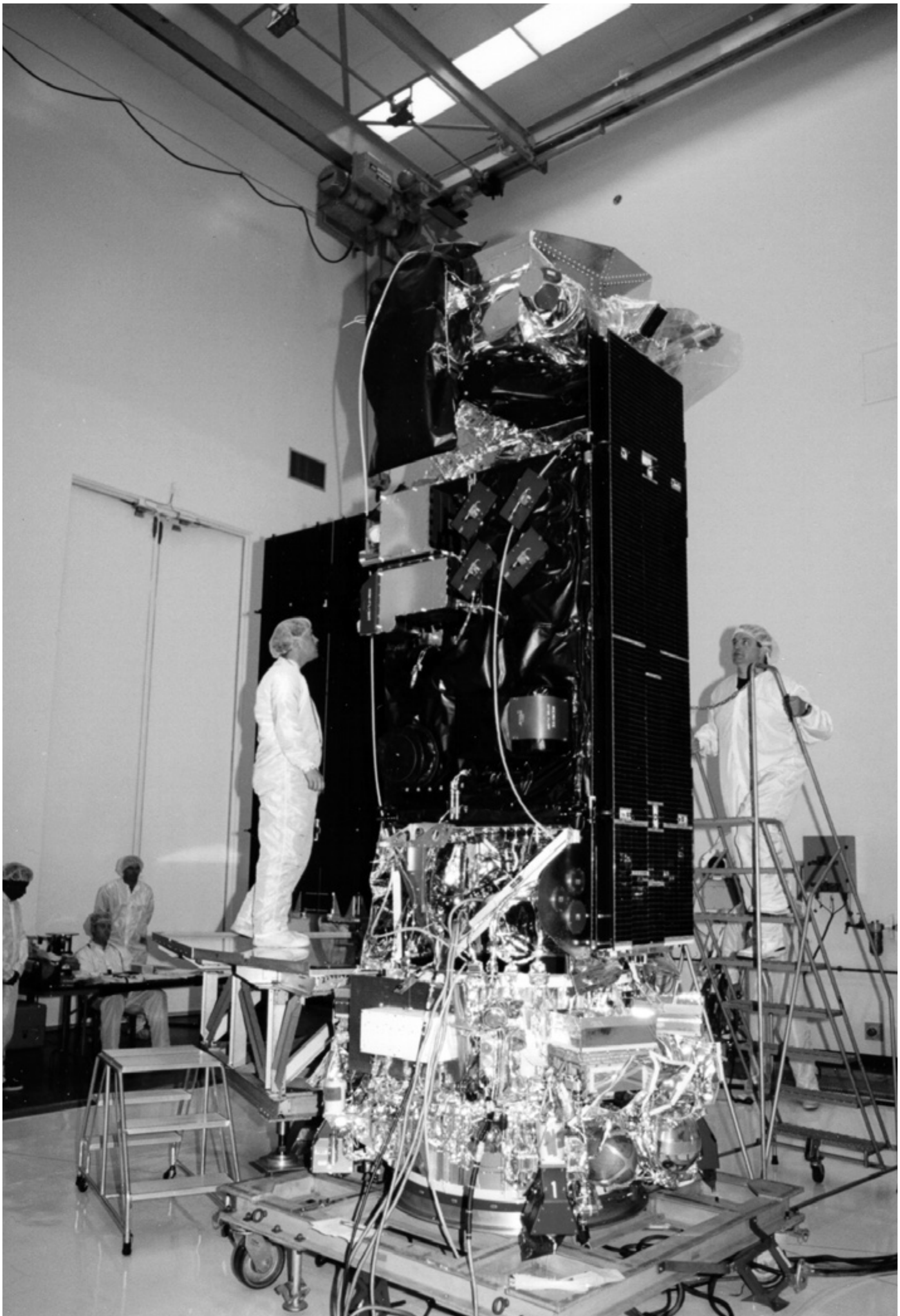
259. Siddiqi, *Challenge to Apollo.*

260. Lieutenant Colonel S. E. Singer, "The Military Potential of the Moon," *Air University Quarterly Review* 11 (summer 1959): 31–53.

261. Anthony M. Springer, "PROJECT ADAM, The Army's Man in Space Program," *Quest: The History of Spaceflight Magazine* 3, nos. 2–3 (1994): 46–47; Anthony M. Springer, "Securing the High Ground: The Army's Quest for the Moon," *Quest: The History of Spaceflight Quarterly* 7, no. 2 (1999): 34–39.

262. William E. Burrows, "Securing the High Ground," *Air & Space Smithsonian* 8 (December 1993/January 1994): 64–69; Jeffrey T. Richelson, "Shootin' for the Moon," *Bulletin of the Atomic Scientists* (September/October 2000).

263. Joshua Stoff, "The Lunar Module's Evil Twin," *Air and Space* (October/November 2000).



Technicians check out DMSP Block 5D-3 satellite, late 1990s. *(Official USAF photo. Air Force Space Command, Office of History)* and Development Board, which was to help coordinate academic efforts for science and technology development after World War II and into the 1950s.

Science experiments aboard American V-2 rocket firings in the late 1940s and early 1950s were coordinated by the Naval Research Laboratory. These military-supported experiments, along with a variety of ground-based studies of the upper atmosphere, were the training ground for many of NASA's early space scientists. Similarly, all of the early space science experiments placed on board pre-NASA Explorer and Pioneer missions were military-funded.

The U.S. Army developed the initial Television and Infrared Observation System (TIROS) weather satellite program, which it turned over to NASA in 1958. The military continued funding certain aspects of space science even after NASA's arrival on the scene in late 1958 and created its own operational programs to monitor Earth and space weather due to their impact on a variety of military operations. The National Reconnaissance Office modified the TIROS design to create the Defense Meteorological Satellite Program (DMSP), which was to ensure that CORONA photography over the Soviet Union took pictures of the ground instead of cloud tops. DMSP continued under USAF control until 1998, supporting a variety of tactical as well as strategic uses. In May 1998, operational responsibility for DMSP transferred to the National Oceanic and Atmospheric Administration (NOAA). Interestingly, the National Weather Service used the DMSP as the basis for its operational satellites in the 1960s instead of NASA's Nimbus. In the early 21st century, military and civilian needs are to be met with the National Polar-Orbiting Environmental Satellite System (NPOESS).

As the impact of solar storms on radio communication became increasingly apparent, both civilian and military groups established groups to monitor space weather and issue warnings and advisories to satellite operators. In the 1980s and 1990s, the military's desire to test ABM technologies in space without violating the ABM Treaty led to the Clementine program, which found surprising evidence for water on the Moon. In the Soviet Union, the Meteor weather satellite program was a military-civilian system from the start, with military specifications provided by the Third Directorate of the Chief Directorate of Reactive Armaments (GURVO) and the design handled by the All-Union Scientific Research Institute of Electromechanics (VNIIEM).

Another major scientific and application initiative was the development of geodesy. This was crucial for military operations planning, both for airborne and ballistic missile strikes from the U.S. to the USSR and vice versa. In the 1950s, knowledge of the exact size and shape of the Earth was insufficient for ballistic missile targeting, as the uncertainty in the distance from North American to Asia was in error between 20 to 30 miles. In addition, the Earth's shape influences the gravity field, which affects ballistic missile trajectories. Thorough mapping of the Earth's surface was essential and was advocated by

Amrom Katz of RAND Corporation in the late 1950s. Development work began on mapping cameras for the USAF Samos program. However, mapping from space began in earnest with the U.S. Army in 1959, when it started the Argon program, which put the KH-5 mapping camera on board CORONA spacecraft. Other mapping cameras were also developed and integrated with the CORONA program.

The other aspect to geodesy was the study of the Earth's gravitational field through experimental satellites. Scientists developed several techniques. One was to measure a satellite's position in orbit through visual sightings at different points on the Earth, such as occurred with the 1960s American Echo 1 and PAGEOS (Passive Geodetic Earth Orbiting Satellite) satellites. Another method was to have a satellite send two radio signals at differing wavelengths and then observe the Doppler-effect frequency shifts from the ground. The U.S. Transit system, as well as the French Diapason and Diademe satellites of the 1960s, operated with this principle. Passive satellites with mirrors that can reflect laser beams from Earth have also been launched, such as the French Starlette. Military geodetic satellites have generally predated civilian systems, and civilian geodetic experiments have been among the first satellites of nations with ballistic missiles, such as France and China. The U.S. military began its Anna 1A and 1B optical ranging satellites in 1962, followed quickly by the Gravity Gradient Stabilization Experiment satellites, the Sequential Collation of Range satellites, and the Geodetic Earth Orbiting Satellite. The Soviets started their geodesy experiments with the Sfera series in 1968, followed by the Musson series beginning in 1980. The U.S. Global Positioning System is also used for geodetic purposes.

Sapolsky's history of the Office of Naval Research is a good introduction to the role of ONR.[264] Van Keuren narrates the scientific cover for intelligence gathering by the Naval Research Laboratory, while McDowell provides an overview of its satellites.[265] Leslie's *The Cold War and American Science* describes military interactions with MIT and Stanford, including some related to space.[266] The role of Johns Hopkins University's Applied Physics Laboratory is told by Klingaman.[267] Sturm describes the creation and evolution of the USAF's

264. Harvey M. Sapolsky, *Science and the Navy: The History of the Office of Naval Research* (Princeton: Princeton University Press, 1990).

265. D. K. Van Keuren, "Cold War Science in Black and White: US Intelligence Gathering and Its Scientific Cover at the Naval Research Laboratory, 1948–62," *Social Studies of Science* 31, no. 2 (2001): 207–229; Jonathan McDowell, "Naval Research Laboratory Satellites 60-89," *Journal of the British Interplanetary Society* 50, no. 11 (1997): 427–432.

266. Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993).

267. William K. Klingaman, *APL—Fifty Years of Service to a Nation: A History of the Johns Hopkins University Applied Physics Laboratory* (Laurel, MD: The Johns Hopkins University Applied Physics Laboratory, 1993).

Scientific Advisory Board (SAB) up to 1964.[268] Gorn's *Harnessing the Genie* also discusses the SAB in its relation to technology forecasting.[269] Komons describes the history of the USAF Office of Scientific Research up to the early 1960s.[270] Day's *Lightning Rod* narrates the history of the USAF Office of Chief Scientist.[271] Liebowitz's chronology provides information on the Cambridge Field Station and its evolution to the Air Force Geophysics Laboratory.[272]

Dick describes the long history of the U.S. Naval Observatory and its relationship to astronomy and space science.[273] Doel's general history of pre–Space Age planetary science contains important information about the military's role in its creation.[274] The history of the American V-2 experiments is told in DeVorkin's *Science with a Vengeance*.[275] Bille and Lishock's *The First Space Race* describes the military's role in launching the first satellites, including scientific aspects.[276] Needell's *Science, Cold War and the American State* portrays military-science relationships through the life of Lloyd Berkner, a leader of early Cold War atmospheric and space science.[277] Newell's *Beyond the Atmosphere* and Butrica's *To See the Unseen* both begin with descriptions of military-funded or -approved space science prior to the founding of NASA.[278] Vanguard, along with its Navy origins and science, is described in Green's early NASA history.[279] Paulikas and Strom describe The Aerospace Corporation's early efforts in understanding the space environment.[280] Hendrickx narrates

268. Thomas A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944–1964* (Washington, DC: Office of Air Force History, 1986).

269. Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944–1986* (Washington, DC: Office of Air Force History, 1988).

270. Nick A. Komons, *Science and the Air Force: A History of the Air Force Office of Scientific Research* (Arlington, VA: Historical Division, Office of Information, Office of Aerospace Research, 1966).

271. Dwayne A. Day, *Lightning Rod: A History of the Air Force Chief Scientist Office* (Washington, DC: JSAF Chief Scientist's Office, 2000).

272. Ruth P. Liebowitz, *Chronology: From the Cambridge Field Station to the Air Force Geophysics Laboratory, 1945–1985* (Hanscom AFB, MA: AF Geophysics Laboratory, 1985).

273. Steven J. Dick, *Sky and Ocean Joined: The U.S. Naval Observatory, 1830–2000* (New York: Cambridge University Press, 2002).

274. Ronald E. Doel, *Solar System Astronomy in America: Communities, Patronage, and Interdisciplinary Research, 1920–1960* (Cambridge: Cambridge University Press, 1996).

275. David H. DeVorkin, *Science with a Vengeance: How the Military Created the US Space Sciences after World War II* (New York: Springer-Verlag, 1992).

276. Bille and Lishock, *The First Space Race*.

277. Allan A. Needell, *Science, Cold War and the American State: Lloyd V. Berkner and the Balance of Professional Ideals* (Amsterdam: Harwood Academic Publishers, 2000).

278. Homer E. Newell, *Beyond the Atmosphere: Early Years of Space Science* (Washington, DC: NASA SP-4211, 1980); Andrew J. Butrica, *To See the Unseen: A History of Planetary Radar Astronomy* (Washington, DC: NASA SP-4218, 1996).

279. Green and Lomask, *Vanguard: A History*.

280. George A. Paulikas and Steven R. Strom, "A Decade of Space Observations: The Early Years of the Space Physics Laboratory," *Crosslink* 4, no. 2 (2003): 6–9.

the story of the Soviet Elektron program, which was a scientific response to U.S. discoveries with Explorer.[281]

Day describes the Argon system and other mapping programs linked to CORONA.[282] Geodesy and its links to military space have become topics for recent research, particularly a series of articles by Warner[283] and another series by Cloud.[284] *The Cambridge Encyclopedia of Space* has a good introduction to geodesy that describes the various geodesy missions.[285] Doel has recently ventured into the military's influence on Earth science as well.[286] Cloud looks at the links between the intelligence and civilian remote sensing programs.[287]

The best overview of the origins of the Defense Meteorological Satellite Program is Hall's recently declassified article.[288] This same 2002 *Quest* issue also contains an informative interview with the program's first manager, Thomas Haig.[289] Abel gives a history of DMSP up to 1982; Brandli shows how DMSP was used in Southeast Asia in the 1960s and 1970s; and Day provides a short history on the origins of the program.[290] Bates and Fuller give a gen-

281. Bart Hendrickx, "Elektron: The Soviet Response to Explorer," *Quest: The History of Spaceflight Quarterly* 8, no. 1 (2000): 37–45.

282. Day, "Mapping the Dark Side of the World Part 1," pp. 264–269; Day, "Mapping the Dark Side of the World Part 2," pp. 303–310.

283. Deborah Jean Warner, "Political Geodesy: The Army, the Air Force, and the World Geodetic System of 1960," *Annals of Science* 59, no. 4 (2002): 363–389; Deborah Jean Warner, "From Tallahassee to Timbuktu: Cold War Efforts to Measure Intercontinental Distances," *Historical Studies in the Physical and Biological Sciences* 30, no. 2 (2000): 393–415.

284. John Cloud, "Crossing the Olentangy River: The Figure of the Earth and the Military-Industrial-Academic Complex, 1947–1972," *Studies in the History and Philosophy of Modern Physics* 31B, no. 3 (2000): 371–404; John Cloud, "Imaging the World in a Barrel: CORONA and the Clandestine Convergence of the Earth Sciences," *Social Studies of Science* 31, no. 2 (2001): 231–251; John Cloud, "Hidden in Plain Sight: The CORONA Reconnaissance Satellite Programme and Clandestine Cold War Science," *Annals of Science* 58, no. 2 (2001): 203–209; John Cloud, "Re-viewing the Earth: Remote Sensing and Cold War Clandestine Knowledge Production," *Quest: The History of Spaceflight Quarterly* 8, no. 3 (2001): 4–16.

285. Fernand Verger, Isabelle Sourbès-Verger, and Reymond Ghirardi, with contributions by Xavier Pasco, *The Cambridge Encyclopedia of Space: Missions, Applications, and Exploration* (Cambridge: Cambridge University Press, 2003).

286. Ronald E. Doel, "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA after 1945," *Social Studies of Science* 33, no. 5 (2003): 635–666.

287. Cloud, "Re-Viewing the Earth."

288. R. Cargill Hall, "A History of the Military Polar Orbiting Meteorological Satellite Program," *Quest: The History of Spaceflight Quarterly* 9, no. 2 (2002): 4–25.

289. David Arnold, "An Interview with Colonel Thomas O. Haig," *Quest: The History of Spaceflight Quarterly* 9, no. 2 (2002): 53–61.

290. Major Michael D. Abel, *History of the Defense Meteorological Satellite Program: Origin Through 1982*, Air Command and Staff College Report No. 87-0020 (Maxwell AFB, AL: Air University Press, 1987); Henry W. Brandli, "The Use of Meteorological Satellites in Southeast Asia Operations," *Aerospace Historian* 29, no. 3 (September 1982): 172–175; Dwayne A. Day, "Dark Clouds: The Classified Origins of the Defense Meteorological Satellite Program," *Spaceflight* 43, no. 9 (2001): 382–385.

eral history of military weather forecasting, while Nebeker provides a general history of which the military is a part.[291] Gavaghan discusses the military origins of TIROS and early weather satellites in *Something New Under the Sun*, based largely on interviews with Verner Suomi.[292] Hendrickx's 2004 history of Meteor is the best source for the Soviet and Russian weather satellites.[293]

Space weather and its relationship to the Sun have received little historical attention. Hufbauer's *Exploring the Sun* describes some USAF efforts in solar and space weather observations. Myers wrote a study of space weather operations.[294]

NAVIGATION

Developed initially for nuclear warfare, space-based navigation has become a worldwide commercial and civilian utility, as well as a major contributor to conventional warfare. Space-based navigation developed from ideas generated from tracking the first satellites from Earth. Scientists worked out the nuances of determining precise satellite positions and orbital trajectories. Once they determined the orbital positions and parameters with precision, scientists at Johns Hopkins University Applied Physics Laboratory realized that it was possible to reverse the procedure. Knowing precise positions in orbit, one can use satellites to determine precise positions on Earth. This would be extremely useful for ships, which had to calculate their positions on featureless oceans. Thus was born the Transit program, which used the Doppler effect from satellite radio signals to determine ship and submarine positions. The U.S. Navy was particularly interested, because it needed precise position measurements for its Polaris submarines to determine the initial firing positions of submarine-launched ballistic missiles.

Transit worked well for ships but was inadequate for aircraft, because its signals were useful in only two dimensions and there were not enough Transit satellites to ensure that there were enough signals to triangulate positions at all times. The U.S. Army, Navy, and Air Force all experimented in the 1960s with technologies to improve upon Transit, but each had different capabilities. In 1973, the Secretary of Defense ordered the combination of the various programs and technologies into the Navstar Global Positioning System (GPS)

291. Charles C. Bates and John F. Fuller, *America's Weather Warriors: 1814–1985* (College Station: Texas A&M University Press, 1986); Frederik Nebeker, *Calculating the Weather: Meteorology in the 20th Century* (New York: Academic Press, 1995).

292. Helen Gavaghan, *Something New Under the Sun: Satellites and the Beginning of the Space Age* (New York: Springer-Verlag, 1998).

293. Bart Hendrickx, "A History of Soviet/Russian Meteorological Satellites," *Journal of the British Interplanetary Society* 57, supplement 1, *Space Chronicle* (2004): 56–102.

294. Master Sergeant Gary P. Myers, "A Portrait of the 4000th Satellite Operations Group" (internal report, 1983).

program. The first test satellites were put in orbit in 1978, but not until 1993 was a full constellation of 24 satellites in place. GPS proved its worth in the 1991 Gulf War as it helped guide Army units over the faceless desert, Navy ships around Iraqi minefields, Air Force aircraft to precise target points, and precision weaponry fired from Navy and Air Force units. Since that time, the U.S. military has converted more and more of its munitions to GPS-based precision munitions, since these proved vastly more effective than conventional ordnance. The use of GPS is now tightly woven with virtually all U.S. military operations. In addition, GPS has spawned a vast commercial market, which greatly exceeds the military's use in terms of receivers sold. GPS has become a global utility, which complicates U.S. military plans. Politically, it can no longer simply shut down civilian access to high-precision signals, even though it had originally intended to do so in wartime.

The Soviet Union was not far behind in the development of its own navigational systems. The Soviets first tested the Tsiklon communications and navigation satellite in 1967, and it became formally operational in 1971. Like Transit, it was used primarily for naval navigation. An improved version, Parus, was first tested in 1974 and operational in 1977. The Soviets next fielded an all-service geodetic and navigational system known as Kristal, which was tested for the Soviet Navy in 1971, and the all-service version in 1984. The Global Navigation Satellite System (GLONASS), the equivalent to GPS, first flew in 1982, but since the fall of the USSR, Russia has been unable to maintain the full constellation.

After 2000, China and Japan flew their first navigational satellites, and Europe, in partnership with China, India, and other nations, is beginning its Galileo program, which will sell its services to military as well as civilian users.

Historical information on navigational satellites remains surprisingly limited. For a longer view of U.S. navigation since the 19th century up to GPS, and also because the U.S. Naval Observatory provides the time for GPS, see Dick's *Sky and Ocean Joined*.[295] Gavaghan discusses the early work of John Hopkins University's Applied Physics Laboratory in the creation of Transit,[296] as do Danchik[297] and Guier and Weiffenbach.[298] Qualkinbush gives an overview of Transit.[299] Friedman provides details of the U.S. and Soviet navigational systems in terms of their utility for naval operations, including Transit,

295. Steven J. Dick, *Sky and Ocean Joined*.

296. Gavaghan, *Something New Under the Sun*.

297. Robert J. Danchik, "An Overview of Transit Development," *Johns Hopkins APL Technical Digest* 19, no. 1 (1998): 18–26.

298. William H. Guier and George C. Weiffenbach, "Genesis of Satellite Navigation," *Johns Hopkins APL Technical Digest* 19, no. 1 (1998): 14–17.

299. Robert Qualkinbush, "Transit: The US Navy Pioneer Navigation Satellite," *Journal of the British Interplanetary Society* 50, no. 11 (1997): 403–426.

GPS, Tsiklon, Parus, and Kristal.[300] The GPS story is extremely important but as yet has no full history. Alford provides a history up to 1985.[301] Bradley has a few papers on the subject.[302] Two articles in *Quest* 11, number 3, provide good overviews of the development of GPS: a historical overview by Banther and an interview of Bradford Parkinson, one of the program's founders.[303] Parkinson has written three historical articles on GPS.[304] Chapter 28 in Getting's *All in a Lifetime* discusses his role in early navigation at The Aerospace Corporation, as does his short paper in *IEEE Spectrum*.[305] Rip and Hasik's recent book, *The Precision Revolution*, is an outstanding look at the impact of space-based navigation on war-fighting.[306] Harvey provides a brief overview of Russian navigational satellites.[307] Forden analyzes the functions of China's Beidou regional navigational satellite system.[308]

ANTISATELLITES AND SPACE WARFARE

Both the United States and Russia have had the capability to destroy each other's satellites from the 1960s, with both sides deploying systems. In the United States, antisatellite weapons have been politically sensitive. Because the United States placed such high value on its space reconnaissance capabilities, political leaders have been wary about creating provocative antisatellite

300. Friedman, *Seapower and Space.*

301. Major Dennis L. Alford, *History of the NAVSTAR Global Positioning System (1963–1985)*, Air Command and Staff College Report No. 86-0050 (Maxwell AFB, AL: Air University Press, 1986).

302. George W. Bradley III, "Historical Origins of the Global Positioning System" (prepared for the History of Technology Conference, Andrews AFB, MD, 24 October 1995); George W. Bradley III, "NAVSTAR Global Positioning System Decision" (prepared for the CAMP Military History Symposium, Rapid City, SD, 11 May 2001); George W. Bradley III, "Origins of the Global Positioning System," in *Technology and the Air Force: A Retrospective Assessment*, ed. Jacob Neufeld, George M. Watson, Jr., and David Chenoweth (Washington, DC: Air Force History and Museums Program, 1997), pp. 245–254.

303. Chris Banther, "A Look into the History of American Satellite Navigation," *Quest: The History of Spaceflight Quarterly* 11, no. 3 (2004): 40–48; Steven R. Strom, "An Interview with Dr. Bradford Parkinson," *Quest: The History of Spaceflight Quarterly* 11, no. 3 (2004): 49–59.

304. Bradford W. Parkinson et al., "A History of Satellite Navigation," *Navigation: Journal of the Institute of Navigation* 42, no. 1, special issue (1995): 109–164; Bradford W. Parkinson and Stephen W. Gilbert, "NAVSTAR Global Positioning System—Ten Years Later," *Proceedings of the IEEE* 71, no. 1 (October 1983): 1177–1186; Bradford W. Parkinson, "Introduction and Heritage of NAVSTAR, the Global Positioning System," in *Global Positioning System: Theory and Applications*, ed. Bradford W. Parkinson and James J. Spiker, Jr., vol. 1 (Washington, DC: AIAA, 1996).

305. Ivan A. Getting, *All in a Lifetime: Science in the Defense of Democracy* (New York: Vantage Press, 1989); Ivan A. Getting, "The Global Positioning System," *IEEE Spectrum* (December 1993): 36–38, 43–47.

306. Michael Russell Rip and James M. Hasik, *The Precision Revolution: GPS and the Future of Aerial Warfare* (Annapolis, MD: Naval Institute Press, 2002).

307. Harvey, *Russia in Space: The Failed Frontier?*

308. Geoffrey Forden, "China's Satellite-Based Navigation System: Implications for Conventional and Strategic Forces," *Breakthroughs* 13, no. 1 (spring 2004): 19–28.

(ASAT) weapons, for fear of provoking the Soviet Union into developing the capability. Despite (or regardless of) American fears or sensitivities, the Soviets developed their own ASAT systems.

American antisatellite capabilities were generally direct spinoffs from other technologies and systems. Dyna-Soar, discussed earlier, was to have a satellite inspection and destruction capability. Ballistic missile defense systems, whether Earth- or space-based, were easily modified to attack satellites as well as missiles, at least in low-Earth orbit. Finally, ballistic missiles provided the orbital boost capabilities to launch antisatellite weapons. All that was really needed was to wait for the satellite to get within range of the booster and then fire it with precise timing.

Early ASAT weapons depended on whether nuclear detonations in space could disable satellites. The first American in-space nuclear test occurred with Project Argus, which was launched in August 1958 and detonated a 2-kiloton weapon, while the Explorer IV satellite measured the resulting change in radiation. Further tests, culminating in the much larger 1962 Starfish Prime nuclear tests in space over Johnston Island in the Pacific Ocean, confirmed that in-space nuclear explosions created radiation intensities that were deadly to both friendly and enemy satellites, as well as knocking out electrical power in the Hawaiian Islands hundreds of miles distant. The data from these tests confirmed that nuclear weapons could destroy satellites, but also that they were indiscriminate in their effects, which led shortly thereafter to the U.S. and USSR agreeing to ban nuclear tests in space.

American ASAT testing began seriously in October 1959, when the USAF's project Bold Orion used a B-47 bomber to air-launch a Martin Corporation missile, which came within 4 miles of the Explorer VI satellite. The Navy explored ship- and air-launched ASAT systems, culminating in two air-launched tests in 1962. In the meantime, the USAF was developing the larger scale SAINT, or Satellite Inspector for Space Defense, which started with a General Operational Requirement to develop a satellite defense system in June 1958. The USAF-managed program was contracted to Radio Corporation of America, which designed a rendezvous-capable vehicle with on-board radar to be launched with an Atlas-Agena. As it became clear that SAINT could not intercept some targets of interest, such as Fractional Orbit Bombardment systems, the USAF canceled it, and its mission migrated to Dyna-Soar.

In parallel, the U.S. Army was extending the capability of its Nike-Zeus ballistic missile defense system to have low-Earth-orbit ASAT functions. This became Program 505 Mudflap, which was the first U.S. operational ASAT system, deployed at Kwajalein Atoll from 1963 to 1967. Replacing it was the USAF's Program 437, which used Thor launchers with nuclear warheads launched from Johnston Island to intercept Soviet satellites. It was operational from 1964 to 1970, when it went on standby status before being terminated in 1975.

The Chelomey design bureau, OKB-52, designed the Soviet Istrebitel Sputnikov (IS) co-orbital ASAT satellite, which first flew in November 1963. A series of tests of the system continued through 1971, including operational tests in 1968 in which the IS satellite successfully exploded near its target satellite. After halting for a few years, the Soviets restarted ASAT tests in 1976, which spurred the Ford administration to restart an American ASAT program, the Miniature Homing Vehicle, an air-launched system that used the fourth stage from a Scout launch vehicle to boost it to space. The United States also funded particle beam and laser beam research programs for potential ASAT and BMD applications, as did the Soviet Union. Since the mid-1980s, U.S. ASAT research, if it continues, appears to have been folded into the Strategic Defense Initiative, and later the Ballistic Missile Defense and National Missile Defense programs. Russian ASAT research remains cloaked, but no space tests appear to have occurred since the demise of the Soviet Union. Nonetheless, both nations, as well as China, have the capability to build ASATs.

Although published in 1985, Stares's *The Militarization of Space* remains a good starting reference for antisatellite systems, describing the politics and basic programs of both U.S. and Soviet systems.[309] Manno provides similar information.[310] Kilgo's 2004 *Quest* article provides an overview of U.S. ASAT programs.[311] Chun has written a number of recent articles on the history of U.S. ASAT systems. He describes SAINT in his "A Falling Star."[312] In a later article, "Nike-Zeus' Thunder and Lightning," he narrates the genesis of the Army's Program 505.[313] The story of the USAF's Program 437 is told in *Shooting Down a "Star."*[314] This work draws from Austerman's *Program 437*.[315] The Miniature Homing Vehicle program is described in Stares's book, in Day's "Arming the High Frontier," and in Spires's *Beyond Horizons*.[316] Siddiqi

309. Paul B. Stares, *The Militarization of Space: U.S. Policy, 1945–1984* (Ithaca, NY: Cornell University Press, 1985).

310. Jack Manno, *Arming the Heavens: The Hidden Military Agenda for Space, 1945–1995* (New York: Dodd, Mead, & Co., 1984).

311. Robert Kilgo, "The History of the United States Anti-Satellite Program and the Evolution to Space Control and Offensive and Defensive Counterspace," *Quest: The History of Spaceflight Quarterly* 11, no. 3 (2004): 30–39.

312. Clayton K. S. Chun, "A Falling Star: SAINT, America's First Antisatellite System," *Quest: The History of Spaceflight Quarterly* 6, no. 2 (1998): 44–48.

313. Clayton K. S. Chun, "Nike-Zeus' Thunder and Lightning: From Antiballistic Missile to Antisatellite Interceptor," *Quest: The History of Spaceflight Quarterly* 10, no. 4 (2003): 40–47.

314. Clayton K. S. Chun, *Shooting Down a "Star": Program 437, the US Nuclear ASAT System and Present-Day Copycat Killers*, CADRE Paper No. 6 (Maxwell AFB, AL: Air University Press, 2000).

315. Wayne R. Austerman, *Program 437: The Air Force's First Antisatellite System* (Peterson AFB, CO: Office of History, 1991).

316. Dwayne A. Day, "Arming the High Frontier: A Brief History of the F-15 Anti-Satellite Weapon," *Spaceflight* 46, no. 12 (2004): 467–471; Spires, *Beyond Horizons*.

narrates the history of the Chelomey ASAT system in an article in *Journal of the British Interplanetary Society*.[317] Onkst describes CIA and NRO responses to Soviet antisatellite systems between 1962 and 1971.[318]

Organization, Management, and Acquisition

The history of human activities in space is intimately tied to the development of sophisticated technologies. In military terms, the research and development leading to the creation of these technologies is called "acquisition." The unique characteristics of the space environment drove the creation of new managerial methods for military technology acquisition called "systems management." Space systems are also operated differently from most Earth-based systems, leading to unique operational processes as well. These developmental and operational differences have also led to the creation of new organizations within the services that handle these unique acquisition and operations processes.

In the late 1940s through the early 1960s, the military services competed for "roles and missions" related to nuclear weapons, ballistic missiles, and finally space systems. The novelty of nuclear weapons and of the space environment meant that none of the services had a clear-cut, unchallengeable claim to these technologies or to space. The Army saw ballistic missiles as extensions to its classical artillery. The USAF saw space as a natural extension of flying. The Navy believed space had unique characteristics crucial for its mission on and in the oceans and did not want either the Army or the Air Force to monopolize space.

Army Ordnance handled the bulk of the Army's missile efforts, controlling von Braun's Army Ballistic Missile Agency and funding Jet Propulsion Laboratory (JPL) to develop the Corporal ballistic missile. Early Air Force missile efforts were managed by Air Research and Development Command and Air Materiel Command, which themselves battled over who controlled what portions of the development process. The Navy's efforts were concentrated in the Naval Research Laboratory, with some programs in the Office of Naval Research.

Sputnik highlighted American space deficiencies, leading to a variety of changes. The Advanced Research Projects Agency (ARPA) was formed to coordinate military space activities. However, it was unsuccessful in this role,

317. Siddiqi, *Challenge to Apollo*; Asif A. Siddiqi, "The Soviet Co-Orbital Antisatellite System: A Synopsis," *Journal of the British Interplanetary Society* 50, no. 6 (1997): 225–240.

318. D. H. Onkst, "Check and Counter-Check: The CIA's and NRO's Response to Soviet Anti-Satellite Systems, 1962–1971," *Journal of the British Interplanetary Society* 51, no. 8 (August 1998): 301–308.

and the services pushed ARPA aside to instead focus on advanced research in which the services were not immediately interested. Space was too important to be left to a separate agency. The DOD also created the Deputy Secretary of Defense for Research and Engineering (DDR&E) to coordinate and control military research, while the Secretary of Defense was given more budget authority, which Robert McNamara in the 1960s used to exert control over the services. By the end of the 1950s, the Army had mostly lost the battle for space, relinquishing JPL and ABMA to NASA. However, it retained programs in ballistic missile defense, playing the leading role for BMD and for the Program 505 Mudflap antisatellite system. The Navy successfully prevented an Air Force monopoly, retaining operational control of satellites intended for naval support such as Transit.

The Air Force won the majority of the turf battles, partially assisted by its concept of "aerospace," the "indivisible medium" of air and space that the Air Force claimed could not be separated and was the natural single medium for operations above the Earth's surface. In 1961, the USAF reorganized its research and development activities, creating Air Force Systems Command for the acquisition of all major programs. Since all space programs were, in the early days, development programs, this centralized the management of many NS space systems. McNamara rewarded the USAF by officially awarding it the bulk of the "space mission."

However, this was only a partial bureaucratic victory, because other organizations gained or retained influence over certain aspects of NS space. This included the National Reconnaissance Office, which forced the USAF to share responsibility for reconnaissance satellites with the Central Intelligence Agency, and the Defense Communications Agency, which exerted control over various aspects of communications satellites and ground systems. Other organizations that remained involved with military space included Lincoln Laboratory, which was funded by all three services, and the National Security Agency, which operated ground stations that received and interpreted signals intelligence data.

The next major changes to the organization of American NS space occurred in the early 1980s, due to two major spurs: the Space Shuttle and Reagan's Strategic Defense Initiative. By the late 1970s, the USAF was building new facilities to handle Space Shuttle military operations, including a launch pad at Vandenberg AFB, a new control facility in Colorado Springs, as well as classified facilities at NASA's Johnson Space Center near Houston. The question of what organization would handle Shuttle operations, as well as Reagan administration concerns about the USAF's fractured space operations, led the USAF to centralize its satellite operations into a new major command, USAF Space Command, based in Colorado Springs. The Army and Navy followed suit, creating Army Space Command and Naval Space

Command, respectively. The next step was to create a single unified command, called United States Space Command, to centralize operational control of all military space assets. Space Command eventually wrested control of launch operations from Systems Command, and Systems Command itself was soon deactivated, with its functions handed to a newly created Air Materiel Command, which brought USAF organizational changes full circle, almost identical to its late-1940s form. In the early 2000s, after the 11 September 2001 terrorist attacks on the World Trade Center and the Pentagon, U.S. Space Command was deactivated and its functions split between Strategic Command and a new Northern Command that concentrated on defense of the North American continent.

In the Soviet Union, ballistic missile and space forces evolved differently. Initially, ballistic missiles and the early space programs were coordinated among several research institutes and design bureaus but organized by Sergei Korolev's Special Design Bureau-1 (OKB-1) in Kaliningrad near Moscow. The Soviet leadership soon fomented internal competition for ballistic missiles by giving responsibility for some of these systems to Mikhail Yangel's OKB-586 in Dnepropetrovsk, which soon moved into spacecraft design as well. A third design bureau, Vladimir Chelomey's OKB-52 in Reutov, gained strength during Nikita Khrushchev's reign, influenced by the fact that Chelomey hired Khrushchev's son, Sergei. Chelomey developed ballistic missiles, as well as antisatellite systems and the Almaz manned reconnaissance orbital station. While these "big three" design bureaus were the most prominent, many others were involved with specialized aspects of Soviet military space programs, from subsystems to specific satellite types, such as Mikoyan's OKB-155 that worked on Spiral, Kozlov's OKB-1 Branch 3 that focused on reconnaissance, Savin's OKB-41 that worked on EORSAT and RORSAT, etc.

Most design bureaus reported to the Ministry of Armaments (MV) until 1965, when they were transferred to the Ministry of Machine Building (MOM) under Dmitry Ustinov. Some design bureaus, such as Mikoyan's, reported to the Ministry of Aviation Industry. In the 1950s and 1960s, the Soviets kept design, accomplished in the design bureaus, separate from production, handled in a variety of factories and plants. In the mid-1970s, the Soviets combined design bureaus and associated factories into Scientific-Production Associations, or NPOs. Thus OKB-1 and various bureaus combined into NPO Energia, while OKB-52 became NPO Mashinostroyenia and OKB-586 became NPO Yuzhnoye.

System operations were handled through the Ministry of Defense, which controlled the Army, Navy, and Air Force. Nikita Khrushchev, wanting to emphasize the importance of ballistic missiles, created the Strategic Missile Forces (or Missile Forces of Strategic Designation—RVSN), which from 1959 to 1981 operated ballistic missile and space systems. Air defense systems, which evolved into the ballistic missile defense and warning systems, were operated by the Forces of Anti-Missile Defense (V-PRO), formed in 1958. Soviet military space programs were centralized in 1964 in the Central Directorate of Space Systems (TsUKOS) of the RVSN and, in 1970, called the Chief Directorate of the Space Systems (GUKOS). In 1981, GUKOS was separated from the RVSN and placed directly under the Ministry of Defense. Renamed the Directorate of the Space Systems Commander (UNKS) in 1986, space systems were formed into a separate military service in 1992, the Military Space Forces (VKS). Between 1997 and 2001, the military space forces were once again subordinated to the RVSN but, in 2001, were once again made an independent force, the Space Forces (KVR). In 2000, when the National Air Defense service was disbanded, its strategic defense functions were transferred to the Space Forces.

China's military space program began when Tsien Hsue-Shen, a brilliant rocket theorist working for the California Institute of Technology and a founding member of JPL, returned to Communist China from the United States in 1955. In January 1956, the government founded the Institute of Mechanics in Beijing with Tsien in charge. By October, the government heeded Tsien's proposal to develop rockets, creating the Fifth Academy of the Ministry of National Defense, with Tsien at its head. The Fifth Academy acquired Soviet R1 and R2 missiles, along with Soviet technicians and blueprints. The Chinese satellite program began on a small scale when engineers from the Shanghai Institute of Machine and Electrical Design went to Beijing to work with Tsien. They returned to Shanghai and started to work, but not until 1965 did the Shanghai institute, under the authority of the Seventh Ministry of Machine Building (the Fifth Academy's new designation) and with assistance from the Chinese Academy of Sciences, get authorization to work with local factories to build satellites. The Shanghai group eventually became the Shanghai Academy of Spaceflight Technology. In 1982, the Seventh Ministry became the Ministry of Space Industry (MASI), which had several academies under it developing various systems and subsystems. Information on other military space organizations exists through primary sources, but there has been little historical work published in open literature.

The evolving organizational structures reflect a deeper set of evolving managerial and engineering processes that were also created along with space systems. Ballistic missile and space systems both require levels of reliability significantly higher than most typical Earth-bound technologies. Neither ballistic missiles nor space systems (with a few exceptions like the Shuttle orbiter) return once placed in space; therefore, components, except for software, cannot be replaced. Rocket engines are extremely dangerous and have extreme temperatures and pressures. The space environment also has extremes of temperature along with radiation, while the lack of air confounds conventional heating and cooling methods. Finally, ballistic missiles and space systems are composed of a multiplicity of individually complex technologies, connected in complex ways.

The combination of these factors led designers to create systems engineering, which is the set of methods to coordinate the organizational communication and complexity of space systems. These methods, which include environmental and systems testing, quality control, change control, design reviews, and configuration control, came to symbolize the extremes of preplanning, controlled manufacturing, and rigorous testing that characterized the space industry. They went hand in hand with managerial innovations such as project management, configuration boards, matrix management, network scheduling tools, and program control rooms. Starting with ballistic missile programs of the U.S. Army, Navy, and Air Force, these methods formed through the mutual interactions of government, industry, and academia and led also to the creation of nonprofit organizations such as RAND Corporation, The Aerospace Corporation, and MITRE Corporation to help the government analyze and coordinate complex technological systems. By the mid-1960s, the bulk of these processes and institutions were in place, as the DOD instituted systems management across all of the services. Since that time, a variety of managerial reforms have been attempted, which somewhat modify these techniques or allow flexibility for program managers to select from a menu of the systems management tools. However, at the start of the 21st century, the core of these methods remained in place for space systems and ballistic missiles.

Virtually all military organizations have institutional histories, and thus there are a host of internal studies that either have been or someday will be declassified. These generally provide a solid base for institutional and managerial histories. I will not attempt to describe them all here. The best procedure for historians is to consult the military organization (or its successor) in which they are interested and request access to the appropriate institutional histories, as well as starting with the regular publications described below.

Spires's *Beyond Horizons* is the best starting point for the USAF's space organization and executive management. Neufeld's *Ballistic Missiles in the USAF* provides a similar basis for ballistic missiles,[319] as does Schaffel's *The Emerging Shield* for continental defense. Waldron provides an overview of the Space and Missile Systems Center.[320] No such overview works exist for the U.S. Army's space efforts, or for the U.S. Navy, ARPA, or the Strategic Defense Initiative Organization and its successors. A few lower-level monographs and articles exist. Neufeld's *Research and Development in the United States*

319. Neufeld, *Ballistic Missiles in the United States Air Force.*

320. Waldron, *Historical Overview of the Space and Missile Systems Center.*

Air Force is an interview with key actors: Bernard Schriever, James Doolittle, Samuel Phillips, Robert Marsh, and Ivan Getting.[321] Tunyavongs describes the politics of the foundation of Air Force Space Command.[322] Sapolsky's *Science and the Navy* narrates the history of ONR, while McDowell describes a variety of Naval Research Laboratory satellite projects.[323] Sigethy's 1980 dissertation on the organization of USAF basic research is a good stating point for that area.[324] Lambeth's short 2004 article in *Air Force Magazine* describes some of the politics of military space.[325]

Institutional histories of the intelligence space organizations exist, but most remain classified. However, some of these histories have become available over time. The National Security Archive at George Washington University has a variety of original documents, many of which are posted online, regarding the intelligence space programs, in particular those of the CIA, NRO, and NSA.[326] Richelson's "Undercover in Outer Space" provides an overview of the NRO.[327] Perry's declassified history, *Management of the National Reconnaissance Program, 1960–1965*, is an outstanding early work on the organizational problems of reconnaissance.[328] Laurie reviews the relationship of the NRO and Congress.[329] Other points of view of the NRO include the CIA's *Office of Special Projects, 1965–1970* and *CORONA Program History.*[330] Day describes the relationships between some of these various histories in his 2000 "Rashomon in Space."[331]

U.S. military–funded nonprofits and academically managed organizations have received their share of historical work, both from the nonprofits

321. Jacob Neufeld, ed., *Research and Development in the United States Air Force* (Washington, DC: Center for Air Force History, 1993).

322. T. Tony Tunyavongs, "A Political History of the Establishment of Air Force Space Command," *Quest: The History of Spaceflight Quarterly* 9, no. 1 (2001): 31–43.

323. Sapolsky, *Science and the Navy*; McDowell, "Naval Research Laboratory Satellites 60-89," pp. 427-432.

324. Robert Sigethy, "The Air Force Organization for Basic Research, 1945–1970: A Study in Change" (Ph.D. diss., The American University, 1980).

325. Benjamin S. Lambeth, "A Short History of Military Space," *Air Force Magazine* 87, no. 12 (2004): 60–64.

326. George Washington University, *The National Security Archive*, *http://www.gwu.edu/~nsarchiv/index.html*.

327. Jeffrey T. Richelson, "Undercover in Outer Space: The Creation and Evolution of the NRO," *International Journal of Intelligence and CounterIntelligence* 13, no. 3 (fall 2000): 301–344.

328. Robert Perry, *A History of Satellite Reconnaissance*, vol. 5, *Management of the National Reconnaissance Program, 1960–1965* (Washington, DC: NRO, 1969).

329. Clayton D. Laurie, *Congress and the National Reconnaissance Office* (Washington, DC: Office of the Historian, NRO, June 2001).

330. *Office of Special Projects, 1965–1970*, vol. 1 (Washington, DC: CIA, 1973), chaps. I–II; Directorate of Science and Technology, CIA, "CORONA Program History, vol. 2, Governmental Activities" (internal document, 19 May 1976).

331. Dwayne A. Day, "Rashomon in Space: A Short Review of Official Spy Satellite Histories," *Quest: The History of Spaceflight Quarterly* 8, no. 2 (2000): 45–53.

themselves and from scholars. Mark and Levine provide an overview of these institutions.[332] RAND Corporation is the most famous of these organizations, whose history is described in an early book by Smith, in Jardini's dissertation, and, most recently, by Collins.[333] Baum describes the RAND spinoff for air defense, System Development Corporation.[334] Freeman describes MIT's Lincoln Laboratory, also initially established for air defense, as was the MITRE Corporation, which wrote its own internal history, with a more recent history by Dyer and Dennis.[335] The Aerospace Corporation did its own internal histories up to 1980 and had a couple of other student thesis histories written about it in the early 1970s.[336] Koppes provides an excellent history of JPL through 1980, including its military roots.[337]

The history of the U.S. aerospace industry from the standpoint of businesses, which are contracted by the military, is best overviewed in Bilstein's *The American Aerospace Industry.*[338] Markusen et al. perform a series of local economic impact studies of military contracting and influences, which include the space sector, in *The Rise of the Gunbelt.*[339] Similar studies for Colorado are Sturdevant and Spires's "Mile-High Ventures" and Spires's "Walter Orr Roberts."[340] Baker and Baker provide a similar story for the foundation of the

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332. Hans Mark and Arnold Levine, *The Management of Research Institutions: A Look at Government Laboratories* (Washington, DC: NASA SP-481, 1984).

333. Bruce L. R. Smith, *The RAND Corporation* (Cambridge, MA: Harvard University Press, 1966); David Jardini, "Out of the Blue Yonder: The RAND Corporation's Diversification into Social Welfare Research, 1946–1968" (Ph.D. diss., Carnegie Mellon University, 1996); Martin J. Collins, *Cold War Laboratory: RAND, the Air Force, and the American State, 1945–1950* (Washington, DC: Smithsonian Institution Press, 2002).

334. Claude Baum, *The System Builders: The Story of SDC* (Santa Monica, CA: System Development Corporation, 1981).

335. Eva C. Freeman, ed., *MIT Lincoln Laboratory: Technology in the National Interest* (Lexington, MA: Lincoln Laboratory, MIT, 1995); MITRE Corporation, *MITRE: The First Twenty Years, A History of MITRE Corporation, 1958–1978* (Bedford, MA: The MITRE Corporation, 1979); Dyer and Dennis, *Architects of Information Advantage.*

336. *The Aerospace Corporation: Its Work, 1960–1980* (El Segundo, CA: The Aerospace Corporation, 1980); *The Aerospace Corporation: Its People, 1980* (El Segundo, CA: The Aerospace Corporation, 1980); *The Aerospace Corporation, 1960–1970, Serving America* (El Segundo, CA: The Aerospace Corporation, 1970); James Franklin Wheeler, "The Aerospace Corporation, Past, Present, and Future" (master's thesis, Air Force Institute of Technology, Air University, 1973); Harold P. Wheeler, "The Aerospace Corporation, Then and Now," Air War College Research Report no. 4474 (Maxwell AFB, AL: Air University, 1971).

337. Koppes, *JPL and the American Space Program.*

338. Roger E. Bilstein, *The American Aerospace Industry: From Workshop to Global Enterprise* (New York: Twayne Publishers, 1996).

339. Ann Markusen, Scott Campbell, Peter Hall, and Sabina Deitrick, *The Rise of the Gunbelt: The Military Remapping of Industrial America* (Oxford: Oxford University Press, 1991).

340. Rick W. Sturdevant and David N. Spires, "Mile-High Ventures: Highlights from Colorado Aerospace History, 1923–1997," *Journal of the West* 36, no. 3 (July 1997): 67–77; David N. Spires, "Walter Orr Roberts and the Development of Boulder's Aerospace Community," *Quest: The History of Spaceflight Quarterly* 6, no. 4 (winter 1998): 5–14.

space community in Utah.[341] Commercial space systems have had an increasing impact on military space. An overview of these issues is found in Klotz and in Logsdon and Acker.[342]

There are a number of works about various aerospace companies, including their contracts and relations with the military. These include Aerojet,[343] Boeing,[344] Convair,[345] General Dynamics,[346] General Electric's Aerospace Group,[347] Itek,[348] Lockheed,[349] McDonnell Douglas,[350] Martin Marietta,[351] Reaction Motors,[352] Rocketdyne,[353] Thiokol,[354] and TRW.[355]

Siddiqi's *Challenge to Apollo* is the best starting point for the institutional history of the Soviet ballistic missile and space programs,[356] along with his 1997 *Spaceflight* article that he later put into an appendix in *Challenge to Apollo.* The other essential reference is Zaloga's *The Kremlin's Nuclear Sword*.[357] A simple introduction to the organizational evolution of the Soviet and Russian

341. Doran J. Baker and Kay D. Baker, "Outer Space Exploration from Utah: Leon Linford and Rocket Science," *Quest: The History of Spaceflight Quarterly* 12, no. 3 (2005): 6–15.

342. Frank G. Klotz, *Space, Commerce, and National Security* (New York: Council on Foreign Relations Press, 1998); John M. Logsdon and Russell J. Acker, eds., *Merchants and Guardians: Balancing U.S. Interests in Global Space Commerce* (Washington, DC: Space Policy Institute, George Washington University, May 1999).

343. *The Aerojet: The Creative Company* (Los Angeles: Stewart F. Cooper Company, 1995).

344. Eugene E. Bauer, *Boeing in Peace and War* (Enumclaw, WA: Taba Publications, 1991); Guy Norris and Mark Wagner, *Boeing* (Osceola, WI: MBI Publishing, 1998); T. M. Sell, *Wings of Power: Boeing and the Politics of Growth in the Northwest* (Seattle: University of Washington Press, 2001); Robert J. Serling, *Legend and Legacy: The Story of Boeing and Its People* (New York: St. Martin's Press, 1992).

345. Bill Yenne, *Into the Sunset: The Convair Story* (Lyme, CT: Greenwich Pub. Group, 1995).

346. Roger Franklin, *The Defender: The Story of General Dynamics* (New York: Harper & Row, 1986); Jacob Goodwin, *Brotherhood of Arms: General Dynamics and the Business of Defending America* (New York: Times Books, 1985).

347. Major A. Johnson, *Progress in Defense and Space: A History of the Aerospace Group of the General Electric Company* (Major A. Johnson, 1993).

348. Jonathan Lewis, *Spy Capitalism: ITEK and the CIA* (New Haven, CT: Yale University Press, 2002).

349. Walter Boyne, *Beyond the Horizons, The Lockheed Story* (New York: St. Martin's Press, 1998).

350. Douglas J. Ingells, *The McDonnell Douglas Story* (Fallbrook, CA: Aero Publishers, 1979); Bill Yenne, *McDonnell Douglas: A Tale of Two Giants* (London: Arms and Armour, 1985).

351. William B. Harwood, *Raise Heaven and Earth: The Story of Martin Marietta People and Their Pioneering Accomplishments* (New York: Simon & Schuster, 1993).

352. Frederick I. Ordway III and Frank H. Winter, "Reaction Motors Inc.: A Corporate History," AIAA Paper 82-277, 1982.

353. *Thirty Years of Rocketdyne* (Canoga Park, CA: Rocketdyne Division, Rockwell International Corporation, 1985).

354. E. S. Sutton, "From Polymers to Propellants to Rockets—A History of Thiokol," AIAA Paper 99-2929 (35th AIAA/American Society of Mechanical Engineers/Society of Automotive Engineers/American Society for Engineering Education Joint Propulsion Conference and Exhibit, Los Angeles, CA, June 1999).

355. Davis Dyer, *TRW: Pioneering Technology and Innovation Since 1900* (Boston: Harvard Business School Press, 1998).

356. Siddiqi, *Challenge to Apollo.*

357. Zaloga, *The Kremlin's Nuclear Sword.*

military space forces is provided in Gorin's "Russian Space Forces" article in the forthcoming ABC-CLIO space history encyclopedia, *Space Exploration and Humanity.*[358] Berkowitz provided an early look at the organization of the USSR's space units.[359] For a first-person view of the early organization of Soviet rocketry, see Chertok's recently translated memoir.[360] Clark provides an overview history of Yangel's design bureau, now Yuzhnoye.[361]

For China, Chang's biography of Tsien Hsue-Shen, *Thread of the Silkworm*, is the best starting point.[362] Chapter 4 of Johnson-Freese's *The Chinese Space Program* provides a basic organizational overview and history, as does Harvey's *China's Space Program.*[363]

On acquisition and management, Lonnquest's 1996 dissertation, "The Face of Atlas," is an outstanding study of Bernard Schriever's role in the creation of the Atlas ballistic missile. Johnson's *The United States Air Force and the Culture of Innovation* investigates the development of management and systems engineering of USAF ballistic missile and air defense programs in the 1950s, while *The Secret of Apollo* contains a shorter version of the ballistic missile story but adds JPL, the NASA manned space program, and the early European space programs.[364] Hughes also tackles these topics in *Rescuing Prometheus.*[365] A short overview of USAF acquisition is provided by Benson.[366] All of these works draw from Gorn's outstanding study, *Vulcan's Forge.*[367] York's 1970 book explains his role in the organization of NS space in *Race to Oblivion.*[368] A critical but historical assessment of USAF acquisition by a key early participant

358. Peter A. Gorin, "Russian Space Forces," in *Space Exploration and Humanity: A Historical Encyclopedia*, ed. Stephen B. Johnson et al. (Santa Barbara, CA: ABC-CLIO, forthcoming, expected publication 2007).

359. M. J. Berkowitz, "To Lift the Veil of Secrecy: USSR Ministry of Defence Space Units," *Journal of the British Interplanetary Society* 46, no. 5 (1993): 191–198.

360. Boris Chertok, *Rockets and People*, vol. 1 (Washington, DC: NASA SP-2005-4110, 2005).

361. Phillip S. Clark, "The History and Projects of the Yuzhnoye Design Bureau," *Journal of the British Interplanetary Society* 49, no. 7 (1996): 267–276.

362. Chang, *Thread of the Silkworm.*

363. John Johnson-Freese, *The Chinese Space Program: A Mystery Within a Maze* (Malabar, FL: Krieger Publishing Company, 1998); Brian Harvey, *China's Space Program: From Conception to Manned Spaceflight* (Chichester, U.K.: Springer-Praxis, 2004).

364. Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945–1965* (Washington, DC: USAF History and Museums Program, 2002); Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore, MD: Johns Hopkins, 2002).

365. Thomas P. Hughes, *Rescuing Prometheus* (New York: Pantheon, 1998).

366. Lawrence R. Benson, *Acquisition Management in the United States Air Force and Its Predecessors* (Washington, DC: Air Force History and Museums Program, 1997).

367. Michael H. Gorn, *Vulcan's Forge: The Making of an Air Force Command for Weapon Acquisition (1950–1985)*, vol. 1, *Narrative* (Andrews AFB, MD: History Office, HQ Air Force Systems Command, 1985).

368. Herbert F. York, *Race to Oblivion: A Participant's View of the Arms Race* (New York: Simon & Schuster, 1970).

can be found in Hall's *The Art of Destructive Management*.[369] Finally, there is currently ongoing a project by the Department of Defense called the Defense Acquisition History Project, which is to produce a six-volume series on the subject in 2007 and 2008.

SPACE POWER THEORY

To date, there is no dedicated monograph on the history of military space doctrine and space power theory, perhaps because there is no single work that commands doctrinal allegiance. Over the centuries, but particularly since the Napoleonic era, military commanders and thinkers have developed a variety of theories and doctrines on the nature of war. As warfare expanded from the land to the sea and to the air, major thinkers for each, which include Sun Tzu, Jomini, and Clausewitz for land warfare; Mahan and Corbett for naval warfare; and Douhet, Mitchell, and Warden for air warfare, developed theories and doctrines that have become the basis for understanding conflict in these domains ever since. To date, no such comprehensive, fundamental theory has been developed for space.

The first attempts to understand the implications of space were reactions to the Nazi V-2 project, such as the 1946 RAND study, which discussed the potential for space assets to enhance certain military activities, such as reconnaissance and weather prediction. RAND also noted the potential political prestige effects of launching the first artificial satellite. In the 1950s, Strategic Air Command's ability to deliver nuclear weapons in a devastating strategic bombing campaign was at the forefront of doctrine, and ballistic missiles were seen as an alternative means to deliver nuclear weapons. Defense-oriented activities, such as early-warning systems, were of distinctly lesser importance.

With the launch of Sputnik in 1957 and the consequent reaction in the United States to launch satellites and to organizationally control space activities, the USAF ultimately won the lion's share of military space programs. General Thomas White defined and propagated the term "aerospace" in 1959 to press the USAF's claim that air and space were a continuous medium with no definite boundary, and hence that it was natural for the Air Force to control operations in this single environment. This claim is debatable at best, but it aided the USAF's bureaucratic cause, as the Kennedy administration in 1961 awarded the USAF the largest share of military space projects and functions.

The next major spur to space power theorizing came in the 1980s, as a theoretical counterpart to the formation of USAF, Army, Navy, and U.S. Space Commands and Reagan's Strategic Defense Initiative. By the late 1980s,

369. Edward N. Hall, *The Art of Destructive Management: What Hath Man Wrought?* (New York: Vantage Press, 1984).

Lupton formulated his four-part conceptual division of space doctrines: sanctuary, survivability, control, and high ground. At the same time, the USAF created a four-part division of its activities, which remain its major means of categorizing its activities: space support, force enhancement, space control, and force application. These two conceptualizations remain the basic frameworks for discussion in the early 21st century, although others have been postulated, the most significant of which is probably the extrapolation from Warden's theory of airpower to postulate space as an economic center of gravity.

Serious theorizing continued into the 1990s and into the first decade of the 21st century, but as yet, no comprehensive theory of space warfare has emerged. A number of recent authors, including Dolman, Hays, Lambakis, Preston, Watts, Gray, Sheldon, and others, have continued the debate.

Specific histories of space power and doctrine are few. Futrell's authoritative *Ideas, Concepts, Doctrine* volumes are the starting point for understanding the history of USAF theories and doctrine, including the intrusion of space into the service.[370] Equally authoritative on the political aspects of the military and some of the debates is McDougall's . . . *The Heavens and the Earth*.[371] Hays's dissertation investigates the relationship between space programs and attempts to create a military space doctrine.[372]

The term "aerospace," along with its evolution and influence, has caught some attention. In two articles, Terry narrates the formulation of the aerospace doctrine in the late 1950s, during the formative years of the space program.[373] Jennings focuses on the conflict over the term "aerospace" itself and its use in doctrine.[374] Rothstein investigates the evolution of the concept from airpower theory.[375] Houchin reviews the impact of hypersonic technologies on aerospace doctrine.[376]

Given the relative paucity of historical work, historians will need to read the major proponents directly. Lupton's *On Space Warfare* is often consid-

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370. Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907–1960*, vol. 1 (Maxwell AFB, AL: Air University Press, 1989); Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1961–1984*, vol. 2 (Maxwell AFB, AL: Air University Press, 1989).

371. McDougall, . . . *The Heavens and the Earth*.

372. Peter Lang Hays, "Struggling Towards Space Doctrine: U.S. Military Space Plans, Programs, and Perspectives During the Cold War" (Ph.D. diss., Tufts University, 1994).

373. Michael R. Terry, "Formulation of Aerospace Doctrine from 1955–1959," *Air Power History* 38, no. 1 (1991): 47–54; Michael Terry, "The Icarus Paradox: Air Force Doctrine and Space Technology," *Quest: The History of Spaceflight Quarterly* 6, no. 3 (1998): 37–43.

374. Frank W. Jennings, "Doctrinal Conflict Over the Word Aerospace," *Airpower Journal* 4 (1990): 46–58.

375. Stephen M. Rothstein, "Dead on Arrival? The Development of the Aerospace Concept, 1944–1958" (master's thesis, School of Advanced Airpower Studies, Maxwell AFB, AL: Air University Press, 2001).

376. Roy F. Houchin II, "Hypersonic Technology and Aerospace Doctrine," *Air Power History* 46, no. 3 (1999): 4–17.

ered the starting point for space power theory.[377] Mantz developed his own theory of space combat in *The New Sword*.[378] Dolman's *Astropolitik* provides another important view on the political aspects of space power.[379] Lambakis's *On the Edge of Earth* is a good overview of current ideas.[380] Preston et al.'s *Space Weapons, Earth Wars* focuses on the political and technical issues of space weapons.[381] Oberg provides an overview of the USAF's official doctrine at the end of the 20th century.[382] Watts provides an informed analysis of trends relevant for military space.[383] Shaw attempts to mirror Alfred Thayer Mahan's influence on history.[384] Two other important recent works on space power theory are by Smith[385] and Lambeth.[386]

Hays et al.'s *Spacepower for a New Millennium* is a compilation of recent papers on U.S. military space, a number of which relate to theoretical aspects.[387] DeBlois's 1999 *Beyond the Paths of Heaven* is a compendium of papers on space power thought.[388] Lambright's collection on space policy contains some theoretical papers.[389] *Air & Space Power Journal* (and its predecessor, *Aerospace Power Journal*, which went by other names earlier) often has papers on military space doctrinal issues.

Although typical for other military functions, there are few works that focus on space systems in combat, for the simple reason that only recently have they been in combat. The First Persian Gulf War of 1991 was the first war in which space systems played an important role, which is documented by Kutyna, Campen, and Berkowitz.[390]

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377. David E. Lupton, *On Space Warfare: A Space Power Doctrine* (Maxwell AFB, AL: Air University Press, 1988).

378. Michael R. Mantz, *The New Sword: A Theory of Space Combat Power* (Maxwell AFB, AL: Air University Press, 1995).

379. Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London: Frank Cass, 2002).

380. Steven Lambakis, *On the Edge of Earth: The Future of American Space Power* (Lexington: University Press of Kentucky, 2001).

381. Robert Preston, Dana J. Johnson, Sean Edwards, and Michael Miller, *Space Weapons, Earth Wars*, MR-1209-AF (Santa Monica, CA: RAND Corporation, 2002).

382. James Oberg, *Space Power Theory* (Washington, DC: GPO, 1999).

383. Barry D. Watts, *The Military Use of Space: A Diagnostic Assessment* (Washington, DC: Center for Strategic and Budgetary Assessments, February 2001).

384. John E. Shaw, "The Influence of Space Power Upon History, 1944–1998," *Air Power History* 46, no. 4 (1999): 20–29.

385. M.V. Smith, *Ten Propositions Regarding Spacepower* (Maxwell AFB, AL: Air University Press, 2002).

386. Benjamin S. Lambeth, *Mastering the Ultimate High Ground: Next Steps in the Military Uses of Space* (Santa Monica, CA: RAND, 2003).

387. Peter L. Hays, James M. Smith, Alan R. Van Tassel, and Guy M. Walsh, eds., *Spacepower for a New Millennium: Space and U.S. National Security* (New York: McGraw-Hill, 2000).

388. Bruce M. DeBlois, ed., *Beyond the Paths of Heaven: The Emergence of Space Power Thought* (Maxwell AFB, AL: Air University Press, 1999).

389. W. Henry Lambright, ed., *Space Policy in the 21st Century* (Baltimore, MD: Johns Hopkins, 2003).

390. Donald J. Kutyna, "Indispensable: Space Systems in the Persian Gulf War," *Air Power History* 46, no. 1 (1999): 28–43; Alan D. Campen, ed., *The First Information War: The Story of Communications,*

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Conclusion—Holes in the Literature

What can we observe from the rather lengthy treatise on sources provided above? First and foremost, there is no area of military space that has a comprehensive treatment with both in-depth analysis and crosscutting synthesis. Some sectors, such as launcher and ballistic missiles, as well as robotic intelligence and reconnaissance, have an extensive literature. Others, such as command and control, communications, navigation, and space power theory, have received very little historical attention. The remainder have had some historical research done but remain significantly underdeveloped: early-warning and space surveillance; ballistic missile defense; human flight; weather and science; antisatellite systems; and organization, management, and acquisition. Needless to say, this leaves the overall state of military space history as significantly underdeveloped, with a few pockets of significant work and a few areas almost completely blank.

Even in areas that have extensive literature, there remain gaping holes. In those sectors with virtually no historical research, almost the entire sector is a historical blank slate. I give my thumbnail assessment of missing research for each sector below.

Holes in the Research

- Ballistic missiles and launch vehicles: synthetic overview, U.S. ballistic missiles after 1965, ballistic missiles outside the United States and Russia/USSR, nuclear warfare strategies after 1960s, effect of the end of the Cold War.

- Early warning and space surveillance: synthetic overview, U.S. overview, space surveillance, Cold War radar systems history.

- Command and control: synthetic overview, U.S./Canada relationship with NORAD, system-of-systems history, conventional versus nuclear command and control, C2 computing after SAGE, C2 and human factors research.

- Ballistic missile defense: synthetic overview, U.S. overview, project histories, SDI and later programs, unbiased political and arms control studies, strategic versus theater missile defense, technical history of BMD.

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Computers, and Intelligence Systems in the Persian Gulf War (Fairfax, VA: Armed Forces Communications and Electronics Association International Press, 1992); Bruce D. Berkowitz, *The New Face of War: How War Will Be Fought in the 21st Century* (New York: Free Press, 2003).

- Robotic intelligence and reconnaissance: synthetic overview, non-U.S. reconnaissance, post-CORONA reconnaissance, politics of commercial remote sensing, uses of satellite intelligence, economics of sector.

- Military human flight: synthetic overview, military-civilian relationships with astronauts, aerospace medicine, hypersonic technologies overview, Space Shuttle and Buran military aspects, Raketoplan/Spiral, technical program histories, MOL versus Almaz.

- Weather and science: synthetic overview, Clementine, military-civilian weather political interactions, project histories, institutions and institutional relationships.

- Navigation: synthetic overview, full project histories, non-U.S. navigation systems, strategic to tactical and commercial applications, politics and economics of navigation.

- Antisatellite systems and space warfare: synthetic overview, full-length project studies (both U.S. and USSR), relationship to BMD and space warfare, new political history (beyond Stares).

- Organization, management, and acquisition: synthetic overview; Army, Navy, DOD, Missile Defense Agency space institutional histories; 1970s–present acquisition; comparative studies to other types of systems (aircraft, C2, naval, etc.).

- Space power theory: synthetic overview; relationships of theory to doctrine and practice; studies of theorists and their theories; relation to other military theories; connections to political, technical, and institutional changes.

There would be great value to the militaries of spacefaring nations, governmental leaders and managers, and the general public to have histories of the many areas that remain underdeveloped. Given that the existence of military space activities is no longer classified, and given the changing world since the demise of the Soviet Union and the rise of global terrorism, broader and deeper knowledge of the actual uses of space will be of great benefit. More research, both from the military itself and from external scholars, will be necessary to make the history of national security space as informed and thorough as the great and growing importance of these activities deserves.

Chapter 16

Critical Theory as a Toolbox: Suggestions for Space History's Relationship to the History Subdisciplines

Margaret A. Weitekamp

After the loss of the Space Shuttle *Columbia* in February 2003, I spoke on a number of radio programs. In the days after the accident, I had written a newspaper editorial reflecting on my fellowship year at the National Aeronautics and Space Administration (NASA) Headquarters History Office in 1997–1998. As a result, the small upstate New York college where I was teaching put my name on its Web site as a local space expert. Busy with classes, I accepted the invitations that fit most easily into my schedule. All but one went smoothly. Too late to cancel, I realized that I had agreed to be the guest for a Las Vegas radio personality whose regional following loved him for his right-wing political opinions and his penchant for controversy. Halfway through the hour-long program, a loyal listener began his question with an apology. He had missed my introduction at the beginning of the hour: "I'm sorry," he asked me, "I didn't hear . . . . Are you a NASA critic or a NASA apologist?"

His question took me aback. I did not consider myself to be either. As an historian of 20th-century America, I studied space history because it allowed me to investigate the intersections of many different themes—politics, society, culture, science, technology, gender, and race—all in one subject. Although historians' conclusions certainly support or criticize particular policy decisions, I saw doing space history as investigating what spaceflight efforts could reveal about a particular time and place: how specific historical contexts shaped which projects were pursued, why historical actors made particular decisions, and how spaceflight technologies have been embedded in their cultural contexts. Regrouping, I tried to explain the role of the professional historian to the listener.

For many years, the caller's assessment of space experts as entrenched in one camp or the other—as either boosters/apologists or critics/exposers—would not have been wrong. In a 2000 *Space Policy* article, Roger D. Launius, then the NASA Chief Historian, argued that space history could be categorized into three parts, including two categories that were more sophisticated but not altogether different than the caller's binary options. The first, the "historiography of expectation" (my caller's "apologists"), is, according to Launius, "unabashedly celebratory and includes not only the so-called 'Huntsville School' of writing but also those fascinated with the machinery and those who use space history to promulgate the space exploration agenda for the future." The second group, the exposés, used space history to question the validity of space exploration efforts at all. Finally, Launius outlined a third category of scholarship that he called the New Aerospace History: "professionally-trained scholars of differing ideologies and prerogatives who concentrate on questions other than whether or not space exploration is justifiable."[1]

Launius's choice of name for this school of historiography, the "New Aerospace History," self-consciously positioned the newest space history scholarship as descended from the New Social History advanced beginning in the 1960s and 1970s. By doing so, he emphasized the active engagement of the New Aerospace History with recent scholarship in the broader field of history. At the same time, he marked the place of space history as a growing subdiscipline within a field still shaped by the New Social History. Indeed, the very subject of this paper—a study of the relationship of space history to the history subdisciplines—reflects the proliferation of subject areas created when historians wrestling with questions of race, class, ethnicity, and gender challenged the artificial nature of the consensus school's master narrative. As a result, mapping the 50 years of space history's expansion means surveying it against the shifting background of a complex and changing discipline.

Such a survey requires two different approaches. First, this analysis reviews and outlines space history's evolution since the beginning of the Space Age. Because the aim of this piece is to survey the field, the bibliography included in the notes offers a sample of relevant works but not a complete accounting of any subdivision of the field.[2] Second, the paper offers some perspective on space history's current relationship to the rest of the discipline of history as practiced in the United States. When examined in these two ways, space history exists both in "relation to" other history subdisciplines (a terminology which implies separation from the other subfields and an internal cohesion within space history, two points that deserve questioning in their own right) and in a continually evolving "relationship with" the rest of the discipline. As this essay maps those dynamics, it also offers some suggestions.

Although the New Aerospace History developed in dialogue with current historical scholarship, the insights of the New Social History have still been only incompletely incorporated into space history. This deficit is not

1. Roger D. Launius, "The Historical Dimension of Space Exploration: Reflections and Possibilities," *Space Policy* 16 (2000): 23–38.

2. Asif Siddiqi's chapter in this volume offers a more complete current historiography.

attributable to a lack of source material, but rather to a limited perspective on what it would mean to integrate the study of race, class, ethnicity, and gender into space history more fully. Bringing the insights of the New Social History to space history is not a call for more compensatory histories of the still-understudied women in the space field or for separate histories of each minority group or ethnicity working in any particular segments of space exploration. (Although compensating for past omissions remains a useful contribution to the field, it is just the first step in historical analysis.) If the New Social History has taught historians anything, it is that gender, race, ethnicity, and class exist in every history—for both privileged and marginalized groups. Gender identity shapes the historical experience of both women and men. Racial identity affects the lives of White people just as much as it does for people of color. Bringing this perspective into analyses of technologies or politics requires a new set of tools.

New developments in the humanities—specifically critical theory—offer a toolbox of concepts and methods that will allow space history to delve further into questions of identity, power, and point of view. If the tools of critical theory can be adapted without straying too far from the narrative tradition of historical scholarship (that is, by adopting its principles and insights without overreliance on theoretical terminology, which can become opaque jargon), the result will bring space history into more fruitful dialogue with the rest of the scholarly community while bringing the insights of recent scholarship to a wider readership.

A Brief History of Space History

The active study of space history began with the very first successful orbital flights in the late 1950s. After the flights of Soviet artificial satellites Sputniks I and II in 1957, spaceflight efforts in the United States generated awareness by both participants and observers that these events were historic; the participants were "making history." Because American lawmakers were also cognizant of the history-making potential of U.S. space efforts—and of the need to publicize American achievements to the rest of the world—the 1958 National Aeronautics and Space Act included, alongside the directives for the creation of a civilian space agency, the mandate that NASA "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."[3] In practical terms, this directive provided the basis for the creation and maintenance of NASA's history offices, archives,

3. "National Aeronautics and Space Act of 1958," Public Law 85-568, in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. 1, *Organizing for Exploration*, ed. John M. Logsdon (Washington, DC: NASA SP-4407, 1995), p. 337.

The 1959 NASA Seal. *(NASA photo no. GPN-2002-000195)*

and libraries. The space agency even began a fine arts program, sponsoring a still-ongoing effort to commission artists to record NASA's achievements through sketches, paintings, and other art forms.[4]

The story of how NASA came to interpret its mandate to include a history program began, at least in part, with Melvin Kranzberg, one of the fathers of the history of technology and a key figure in the creation of the NASA History Office. Kranzberg was a faculty member at the Case University of Technology in Cleveland, Ohio, when Case's president, T. Keith Glennan, was asked by President Dwight D. Eisenhower to become the founding Administrator of NASA. In 1958, Kranzberg persuaded Glennan to create a history office at the new civilian space agency in the tradition of the successful history offices working in the armed forces and in other federal agencies. The

4. For history and individual artists in the NASA Art Program, see Anne Collins Goodyear, "The Relationship of Art to Science and Technology in the United States: Five Case Studies,

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founding of the NASA History Office and the beginning of space history as a field occurred at the same time that the broader discipline of history began to see the development of distinct subfields organized by topic and approach.[5]

Around the same time that his discussions with Glennan were inspiring the new NASA History Office, Kranzberg also helped to found the Society for the History of Technology (SHOT). Kranzberg saw the history of technology as the latest development in the study of the past: the newest link in a chain of histories that offered fresh topics of study and modes of analysis to the expanding field. In May 1962, he published an article in *Science* magazine titled "The Newest History: Science and Technology." In it, he compared the history of technology to James Harvey Robinson's *The New History* (1912), published exactly 50 years earlier. As Kranzberg noted, at the same time that Robinson was developing his New History, another historian, George Sarton, was also offering the field a groundbreaking new subject for consideration: a new history of science. In all three cases, changing world events, social movements, and academic developments inspired historians to rethink their conceptions and interpretations of the past.[6]

The development of innovative historical approaches—and thus of new historical subfields—drove the central argument of Kranzberg's *Science* article. For the history of technology, Kranzberg argued, the launch of Sputnik I on 4 October 1957 marked the beginning of a new era. In response, the United States needed not only a technological response in the form of a space program, but also a study of "technology and science as essential components of our culture, affected by and affecting every other aspect of society." Building on the tradition of change and growth in the historical field, Kranzberg saw new histories as extending and expanding a vital and changing discipline. In his words, "Just as the 'new' history triumphed over the 'old' but never succeeded in dislodging it completely, so today the 'new' history is itself being supplemented

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1957–1971" (Ph.D. diss., The University of Texas at Austin, 2002); Anne Collins Goodyear, "NASA and the Political Economy of Art, 1962–1974," in *The Political Economy of Art: Creating the Modern Nation of Culture*, ed. Julie Codell (Newark: University of Delaware Press, forthcoming); Anne Collins, "Art, Technology, and the American Space Program, 1962–1972," *Intertexts* 3, no. 2 (fall 1999): 124–146; Anne Collins Goodyear, "On the Threshold of Space: Norman Rockwell's Longest Step," *Architecture and Design for Space: Vision and Reality* exhibit catalog (New York: Harry N. Abrams, Inc., 2001), pp. 102–107 (exhibit shown at the Art Institute of Chicago, 24 March–21 October 2001); "Robert Rauschenberg's Space-Age Allegory, 1959–1970," in *1998 National Aerospace Conference Proceedings* (Dayton, OH: Wright State University, 1999): 82–91.

5. For Kranzberg's influence on the creation of NASA's History Office, see Roger D. Launius, "NASA History and the Challenge of Keeping the Contemporary Past," *Public Historian* 21 (summer 1999): 63–81.

6. Margaret Rossiter, ed., *Catching Up With the Visions: Essays on the Occasion of the 75th Anniversary of the Founding of the History of Science Society* (Chicago: University of Chicago Book for the History of Science Society, 1999), a supplement to *Isis* 90.

by the 'newest' history."[7] Kranzberg's *Science* article is particularly instructive for a discussion of how today's space history has evolved because his analysis of American historiography up to 1962 offers a useful model for thinking about how new histories expand the discipline of history. In addition, it points out the close link between space history and the history of technology, which continues to be a vital and important subfield for space history.

If the NASA History Office's existence can be traced to Glennan and Kranzberg, its reputation for scholarly rigor began with the first NASA Historian, Eugene "Gene" M. Emme. From the beginning of its life, the NASA History Office worked to balance two major charges: collecting and archiving the history of U.S. civil space exploration efforts for use by historians, scholars, and the press, and interpreting that material to advise the space agency on ongoing decisions. In addition to managing these tasks, Emme put the program on the path to real scholarly publishing. He instituted the practice of peer review for historical manuscripts published by the NASA History Office, a process that parallels the one used by academic presses and one which has allowed NASA's history program to develop into a respected site for both research and publishing. As the first in a series of interpretive volumes recording the details of historic space achievements within a narrative structure, Swenson, Grimwood, and Alexander's *This New Ocean: A History of Project Mercury* set the tone for NASA's authoritative recording of space history. Within its first two decades, NASA's project histories also included books on Gemini, Vanguard, and Apollo.[8] Within the structures of the U.S. space agency, the NASA History Office focused on American space efforts, emphases that also characterized the field of space history generally.

The NASA History Office also began the ongoing relationship between space history and oral history. As a research technique, the tape-recorded interview came into its own in the 1940s and became a useful tool for recording histories both "from the bottom up" and "from the top down."[9] By 1966, the Oral History Association provided a professional organization for oral historians to share their work while developing and refining the ethical and practical guidelines for productive oral histories. For an endeavor like spaceflight,

7. Melvin Kranzberg, "The Newest History: Science and Technology," *Science* 136, no. 3515 (11 May 1962): 463–468.

8. Loyd S. Swenson, Jr., James M. Grimwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury* (Washington, DC: NASA SP-4201, 1966); Constance McLaughlin Green and Milton Lomask, *Vanguard: A History* (Washington, DC: NASA SP-4202, 1970); Barton C. Hacker and James M. Grimwood, *On the Shoulders of Titans: A History of Project Gemini* (Washington, DC: NASA SP-4203, 1977). See also Launius, "NASA History," pp. 63–81.

9. Paul Thompson, *The Voice of the Past: Oral History*, 3rd ed. (Oxford: Oxford University Press, 2000); Edward D. Ives, *The Tape-Recorded Interview: A Manual for Fieldworkers in Folklore and Oral History* (Knoxville: University of Tennessee Press, 1995). The best practical handbook is Donald A. Ritchie, *Doing Oral History: A Practical Guide*, 2nd ed. (Oxford: Oxford University Press, 2003).

which required the work of so many different managers, engineers, scientists, and pilots, oral history became a key means of recording the full history of various space programs, NASA Centers, and historical actors. NASA continues to use oral history as a major tool for collecting, preserving, and disseminating space history.[10]

If the early years of space history (and its relationships with the history subdisciplines) can largely be traced through a history of the NASA History Office, once the field developed into some maturity in the 1980s, the story got much more complex. From where it began in the early 1980s, space history underwent dramatic growth and transformation. Because a full analysis of that historiography would be too long and involved for this piece (and has already been done extraordinarily well elsewhere, as noted above),[11] an outline serves better as a way of noting the relationships between the growing subfield and the changes happening in the discipline of history as a whole. Three events mark key points in the evolution of space history: a 1981 Smithsonian proseminar, Walter McDougall's Pulitzer Prize–winning 1985 book, and Asif Siddiqi's 2000 history of the Soviet space program, *Challenge to Apollo.*

In 1981, a Smithsonian Institution proseminar in space history hosted at the National Air and Space Museum marked the emergence of space history as a recognized field. David DeVorkin and Pamela Mack of the then–Department of Space Science and Exploration called the meeting to bring together scholars working on space history in order to assess the progress made over the previous 15 years. The report of the meeting in *Isis* recorded a successful and growing subdiscipline, noting that "the field is already marked with a respectable number of books, monographs, dissertations, and works-in-progress." The questions being asked at this meeting offer a sense of the state of development of the field. Three issues dominated discussion: first, "Is space history best considered part of the history of science or of the history of technology?"; second, "Can space science be considered a coherent discipline?"; and finally, "How should space historians confront the peculiar state of sources in this field?"[12]

In debating the first question, historians of science and historians of technology who worked on space topics found themselves in active discussion about the commonalities and differences between their home subfields. The discussion of space history's place quickly made it clear just how much space history required the insights of both subdisciplines. Requiring space history to be either one or the other would be insufficient. (The divisions between these

10. See Roger D. Launius, "We Can Lick Gravity But Sometimes the Paperwork Is Overwhelming: NASA, Oral History, and the Contemporary Past," *Oral History Review* 30, no. 2 (summer/fall 2003): 111–128.

11. Launius, "Historical Dimension," *Space Policy*, pp. 23–38.

12. Richard F. Hirsh, "Proseminar on Space History, 22 May 1981," *Isis* 73, no. 266 (1982): 96–97.

two subdisciplines and the professional organizations that represent them are only just beginning to be healed. The November 2005 joint meeting between the Society for the History of Technology and the History of Science Society in Minneapolis, Minnesota, marked a renewed attempt to bridge this gap).[13] As a subject centered on the relationships among science, technology, and the state, the history of spaceflight pushed historians to address science and technology as social and political activities.

Space historians at the 1981 Smithsonian proseminar also shared a common set of anxieties about sources. Many faced significant problems getting full access to documentation that was still considered sensitive during the renewed Cold War tensions of the early Reagan administration. At the same time, massive space projects generated so much paperwork that they became difficult to interpret. In the opinions of those attending the Smithsonian event, government records from active or recently active programs were "abundant but poorly organized." Again, this recorded discussion provides a useful benchmark for assessing space history. Given how much space history would expand by the early 1990s, when the end of the Cold War led to an explosion of newly available materials, the question of sources provides a striking point of comparison.[14]

One of the solutions offered for dealing with incomplete or sensitive records was oral history. The proseminar's organizers quickly took up that charge. Between 1981 and 1990, the Department of Space History at the Smithsonian Institution's National Air and Space Museum organized several oral history projects. These included the Space Astronomy Oral History Project, the Space Telescope History Project, the Glennan-Webb-Seamans Project for Research in Space History, and the RAND History Project. In all, the interviews conducted reflected the principal investigators' interests in space science, as well as in management and political themes in space history. In the final catalog of these oral histories, the organizers acknowledge that their understanding of the interactions between science, technology, and the state changed considerably over the course of the oral history projects. This insight reflects the scholars' own intellectual growth during the course of the project through the 1980s, but it also reflects the state of the field. In the midst of their work, space history underwent an evolutionary leap.[15]

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13. The organizations had unsuccessful joint meetings in Pittsburgh in 1986 and in Madison, WI, in 1991. See Terry S. Reynolds, "From the President's Desk: 'Time to Try Again?'" *SHOT Newsletter* (April 2000), available online at *http://shot.press.jhu.edu/Newsletters/archive/2000_April/presdesk.htm* (accessed 21 April 2005).

14. Hirsh, "Proseminar," pp. 96–97.

15. Martin J. Collins with Jo Ann Bailey and Patricia Fredericks, "Oral History on Space, Science, and Technology: A Catalogue of the Collection of the Department of Space History, National Air and Space Museum" (Washington, DC: Smithsonian Institution, 1993), pp. i–v.

Walter McDougall began his Pulitzer Prize–winning analysis of space history with a metaphor of evolution: the image of the first fish-turned-amphibian. In that moment, he suggested, biological adaptation jumped forward, not in a slow, incremental progression, but in a saltation, an evolutionary leap. According to McDougall, this metaphor also described the transformed relationship between the state and research and development (R&D) in the years after the Second World War. In many ways, . . . *The Heavens and the Earth* was also a saltation for space history. McDougall's work was a watershed book for its comprehensive consideration of space history as a part of political history.[16]

Twenty years later, McDougall's work remains a required first reference on many topics for most space historians (both popular and academic). At a 1997 40th-anniversary conference commemorating the launch of Sputnik, many historians began their analyses with a reference to McDougall's work.[17] In considering how space history exists both in relation to (that is, standing separately) and in active relationship with particular historical subdisciplines, however, McDougall's work solidified a link between space history and political history that remains strong. Few would consider writing a space history without some serious consideration of party politics, national legislators, or foreign and domestic policy. More so, political historians welcome discussion of space history as an avenue into broader topics.

Just as McDougall's example required space historians to place space history in its political context, so also by the mid-1980s, new developments in the history of technology required historians to reconsider how technologies existed as embedded in their social contexts. As a result of the ongoing relationship between space historians and historians of technology (who are often one and the same), space history and the history of technology grew and broadened in similar ways over the years. In a 1986 *Technology and Culture* article, Kranzberg published his famous "six laws of technology," guiding principles that emphasized the role of technology as an inherently human endeavor, embedded in culture. Likewise, space history has deepened its understanding of space technologies—and indeed, of space programs—as embedded in particular social, political, and cultural contexts. Within the Cold War context of the early space race, however, for the first 20 years of space history, most U.S. authors focused on American space efforts, in part because these stories resonated with the public and in part because the ongo-

16. Walter McDougall, . . . *The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), p. 3. Because of its length, . . . *The Heavens and the Earth* is not easily assigned in a classroom setting. A digestible history of space exploration that encompasses the political and social contexts is still needed.

17. "Reconsidering Sputnik: 40 Years Since the Soviet Satellite Symposium" (held in Washington, DC, 30 September–1 October 1997).

ing diplomatic stalemate with the Soviet Union made information about the Soviet side of the story all but impossible to access.[18]

Another saltation for space history happened at the end of the Cold War, when the fall of the Berlin Wall in 1989 presaged the disintegration of the Soviet Union in 1991. Not only did these geopolitical changes have major impacts on the way that spaceflight would be conducted from that point onward (thus requiring historians to rethink how space history would be written from then on), but these changes also created a boom in possibilities for space history. New sources emerged, both through the declassification of military or other classified space projects in the United States and through the release of previously secret sources from the former Soviet Union.

New sources yielded new histories. One that compares to Walter McDougall's in scope and impact is Asif Siddiqi's *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974.* Working in the Russian-language documents made newly available by the release of uncensored records after 1988, Siddiqi reconstructed the history of the Soviet space program from the early 1930s Group for the Investigation of Reactive Engines and Reactive Flight (GIRD) to the end of the N1L3 program in 1974. Comprehensive, detailed, and yet still very readable, his narrative offers new dimensions and backstories to known events, revealing details about the people and the decision-making processes that created the Soviet space program. In doing so, the book presents a clear look at the history of Soviet space efforts, the outlines of which had previously only been gleaned from censored records or American intelligence. The result, Siddiqi suggests, sheds new light on human space exploration as a whole: "What may be possible now is to take a second look not only at the Soviet space program, but also the U.S. space program—that is, to reconsider again humanity's first attempts to take leave of this planet."[19] In the United States, the end of the Cold War also opened new topics for space researchers, permitting histories of previously classified programs (for example, the CORONA spy satellites).[20]

Indeed, the number of topics that constitute space history has multiplied in recent years. As it now stands, space history encompasses the history of human spaceflight, including reevaluations of programs, centers, technologies,

18. Melvin Kranzberg, "Technology and History: 'Kranzberg's Laws,'" *Technology and Culture* 27 (1986): 544–560.

19. Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974* (Washington, DC: NASA SP-2000-4408, 2000), p. x. Also republished as a two-volume set: Asif A. Siddiqi, *The Soviet Space Race with Apollo* (Gainesville: University Press of Florida, 2003), and Asif A. Siddiqi, *Sputnik and the Soviet Space Challenge* (Gainesville: University Press of Florida, 2003).

20. Dwayne A. Day, John M. Logsdon, and Brian Latell, eds., *Eye in the Sky: The Story of the Corona Spy Satellites*, Smithsonian History of Aviation Series (Washington, DC: Smithsonian Institution Press, 1998).

events, and people, including both military and civilian spaceflight projects and technologies.[21] The recent addition of commercial space ventures and a nascent space tourism industry should soon join these topics. Human spaceflight makes up only a part of the picture, however. Space history must also include satellite programs, launch vehicles, and planetary exploration. The history of space science and of astronomy is also a part of space history.[22] Although most of what is written focuses on stories of success, accounts of incomplete, failed, or abandoned projects also illuminate the forces that shape space exploration. And space history is most decidedly international. As the number of countries participating in space efforts has increased, space history reflects an expansion beyond the previous U.S.-Soviet/Russian focus. In part, this breadth of topic and diversity of approach define the New Aerospace History.[23]

The New Aerospace History

More so, however, the New Aerospace History developed in the 1990s as a result of the increasing professionalization of space history. Like other related subdisciplines, space history evolved from histories written by participants and practitioners into a field being advanced by professionally trained historians.[24] Roger D. Launius, the NASA Chief Historian in the 1990s, also led the push for space history to engage the cutting-edge scholarship in the wider discipline. During his tenure leading the NASA Headquarters History Office from 1990 through 2002, Launius worked to develop the Agency's publishing efforts as a way of creating opportunities for a rigorous practice of space history. For instance, in addition to commissioning new volumes for the exist-

21. See, for example, Andrew Chaiken, *A Man on the Moon: The Voyages of the Apollo Astronauts* (New York: Viking Press, 1994); Roger D. Launius, "NASA and the Decision to Build the Space Shuttle, 1969–72," *The Historian* 57 (autumn 1994): 17–34; Robert A. Divine, *The Sputnik Challenge: Eisenhower's Response to the Soviet Satellite* (New York: Oxford University Press, 1993); Roger D. Launius and Howard E. McCurdy, eds., *Spaceflight and the Myth of Presidential Leadership* (Urbana: University of Illinois Press, 1997); W. Henry Lambright, *Powering Apollo: James E. Webb of NASA* (Baltimore: Johns Hopkins, 1995); James J. Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon* (New York: John Wiley & Sons, Inc., 1997).

22. See, for instance, Pamela Mack, *Viewing the Earth: The Social Construction of Landsat* (Cambridge, MA: The MIT Press, 1990); "Developing U.S. Launch Capability: The Role of Civil-Military Cooperation" (paper presented at the American Association for the Advancement of Science conference, Washington, DC, 5 November 1999); David DeVorkin, *Science with a Vengeance: How the Military Created the US Space Sciences After World War II* (New York: Springer, 1993).

23. See, for instance, Margaret A. Weitekamp, *Right Stuff, Wrong Sex: American's First Women in Space Program* (Baltimore: Johns Hopkins, 2004); John Krige and Arturo Russo, "Europe in Space, 1960–1973," European Space Agency SP-1172 (Noordwijk, Netherlands: ESA Publications Division, 1994).

24. Similar trends exist in the history of technology. At the 13 January 2005 meeting of the Historical Seminar in Contemporary Science and Technology at the Smithsonian Institution's National Air and Space Museum, a spirited debate arose between those celebrating the prevalence of professional historians in the field and those lamenting the absence of trained engineers.

ing Special Publications series, Launius also began the NASA Monographs in Aerospace History, a series of slim paperback volumes focused on specific topics. Throughout his efforts, Launius aimed to bring NASA's publishing to a new level of scholarly excellence, an effort that was recognized by the larger history community when the Agency's history books began to win prizes from professional organizations. Through the development of a professionalized history, space history forged new connections with other subdisciplines at the same time that it also became a somewhat more coherent subfield.[25]

As with so many things, the status and standing of space history as a subdiscipline can be measured through its funding and visibility. Several significant fellowships exist for emerging and established scholars. The American Historical Association (AHA) and NASA have offered a joint full-year predoctoral or postdoctoral aerospace history fellowship each year since 1986. And several different fellowships for graduate students (at the master's, predoctoral, and postdoctoral levels) and senior scholars exist at the Smithsonian Institution's National Air and Space Museum. Space history is also a consistent presence at major scholarly conferences including the AHA, the Society for the History of Technology (SHOT), the Organization of American Historians (OAH), and the American Studies Association (ASA).

Space history also has a tradition of gathering scholars and participants to celebrate and commemorate major anniversaries in the history of the field. Beginning with events and symposia held to mark the first 25 years of the Space Age, such conferences have recorded the state of the field at various points in its existence. This very volume follows in that tradition. As the proceedings of the NASA History Division's "Critical Issues in the History of Spaceflight" symposium, the articles contained here offer a current indicator of the subject's breadth and diversity—and of participants' sense of the field as a coherent enough one to warrant such a meeting.[26]

As much as space history has become a more internally coherent field, however, its employment opportunities, graduate study, and publishing trends reflect its roots in many different subdisciplines. Although dedicated space history jobs can be found at NASA (at Headquarters or the Centers), the Smithsonian's National Air and Space Museum, or the Space Policy Institute

25. For instance, the Organization of American Historians (OAH) awarded its 1998 Richard W. Leopold Prize to Andrew Butrica's *To See the Unseen: A History of Planetary Radar Astronomy* (Washington, DC: NASA SP-4218, 1996).

26. Allan Needell, ed., *The First 25 Years in Space: A Symposium* (Washington, DC: Smithsonian Institution Press, 1983); Alex Roland, ed., *A Spacefaring People: Perspectives on Early Spaceflight* (Washington, DC: NASA SP-4405, 1985); Martin J. Collins and Sylvia D. Fries, eds., *A Spacefaring Nation: Perspectives on American Space History and Policy* (Washington, DC: Smithsonian Institution Press, 1991); Stephen J. Garber, ed., *Looking Forward, Looking Backward: Forty Years of U.S. Human Spaceflight Symposium* (Washington, DC: NASA SP-2002-4107, 2002).

Jan Davis and Mae Jemison on STS-47. *(NASA photo no. GPN-2004-00023)*

at George Washington University, most space history experts continue to find homes in non-space-specific academic jobs in history or political science. (In a rare occurrence, the University of Central Florida offered and filled a full-time, tenure-track space history position in 2005.) The many intersections of space history with the other history subdisciplines offer employment opportunities that are at least as ample as any academic field's opportunities are. Likewise, junior scholars engaged in graduate work have focused on space topics while earning degrees in history and political science as well as fields as diverse as geography and communications.[27] Opportunities for publishing peer-reviewed articles also reflect the roots of space history as a topic studied by many different types of historians. Except for *Space Policy*, few professional journals have space topics as a central focus.

The inherently interdisciplinary nature of space history can be seen in some of its best new works. For instance, Howard McCurdy's *Space and the American Imagination* combines social and cultural history with public policy analysis to show how popular culture influenced policy-making. McCurdy analyzes how "space boosters" in the 1950s and 1960s used magazines, television shows, and movies to create the groundswell of support needed to loose the massive amounts of public funding required to carry out space exploration initiatives. McCurdy's detailed analysis persuasively links comics and

27. Kathy Keltner, for example, is writing a communications Ph.D. dissertation at Ohio University.

Congress. What might have seemed like an unlikely junction between unrelated fields is now a connection being followed by other scholars.[28]

Some likely connections are only just being explored. Despite what might seem like natural areas of overlap, very few scholars have actively pursued work at the juncture between environmental history and space history. As areas of history that both study the intersections of science, technology, and culture, space history and environmental history have much to say to each other. In a field that is building on its histories of national parks and natural spaces, environmental history investigates the intersections between nature, technology, and public policy. Environmental historians have taken on roads, cars, and urban/suburban sprawl as topics but have stopped short of dealing with outer space. As much as many environmental historians have not considered outer space as "nature" or even as a natural place, neither have space historians looked to environmental history for ways to think about space as an environment. Environmental history might also offer models for thinking about the Earth and low-Earth orbit as "natural." New work by scholars such as Neil Maher demonstrates the extent to which exploring space is less about finding nature in outer space than it is about obtaining new perspectives on nature on Earth. In the environmental historian's triad of investigating the intersections between nature, technology, and culture, space historians often ignore nature. The need for intersection between these subfields is a development being echoed by historians of science and technology. Both the History of Science Society (HSS) and SHOT now have environmental history special interest groups (called the "Earth and Environment Forum" and "Envirotech," respectively). Despite these forays into interdisciplinarity, space history has often lagged behind the evolution of the discipline as practiced in the United States.[29]

By the 1980s, the New Social History had fundamentally transformed the discipline's practice, becoming formalized through established journals, academic appointments, and professional organizations. The rejection of the consensus school led to renewed attention to the lives of ordinary people and a new set of narratives that challenged the accepted periodization of U.S. and world history. Although critics complained that the field of history was becoming fractured or that a common American identity was being lost,[30] advocates

28. Howard McCurdy, *Space and the American Imagination* (Washington, DC: Smithsonian Institution Press, 1997).

29. Two examples are Neil Maher, "On Shooting the Moon," Gallery in *Environmental History* 9 (July 2004): 526–531, and Erik M. Conway, "The World According to GARP: Scientific Internationalism and the Construction of Global Meteorology, 1961–1980" (paper presented at the International Commission on History of Meteorology, Polling, Germany, 5–9 July 2004). "Envirotech" was founded at the August 2000 SHOT meeting in Munich, Germany.

30. Arthur M. Schlesinger, Jr., *The Disuniting of America: Reflections on a Multicultural Society* (New York: W. W. Norton & Company, 1998).

for the New Social History argued that particular attention to women, laborers, people of color, the poor, or people with disabilities revealed aspects of the past that had been systematically ignored by the previous, more unified narrative. Growing scholarship demonstrated how exclusionary and limited the master narrative had needed to be in order to maintain its cohesiveness.

Through the 1970s and the 1980s, scholars developed subfields with new modes of analysis that focused on questions of difference and power. In 1990, when Eric Foner edited a new collection of essays for the AHA called *The New American History*, in addition to essays on various periods of U.S. history, the volume included attention to six "major themes in the American experience." These included "Social History," "U.S. Women's History," "African-American History," "American Labor History," "Ethnicity and Immigration," and diplomatic history. If these topics can be considered a rudimentary breakdown of the established subfields in American history and of the concerns of the New Social History, then an examination of these areas offers insight into how well space history has engaged each of them. In the parlance of many historians, this longer list is often simplified to class, race, ethnicity, and gender.[31]

Political scientists working on space topics have addressed questions of class or labor history in space history through their analyses of NASA as a complex organization and NASA's management culture. Sadly, these subjects became all too relevant after the losses of two Space Shuttles, *Challenger* in 1986 and *Columbia* in 2003. Both the Rogers Commission and the Columbia Accident Investigation Board diagnosed organizational cultures that had become inured to risk. In addition, they found communication and project management problems that contributed directly to the loss of the two Shuttle crews. As a result, scholars have paid particular attention to NASA's decision-making culture. Many other aspects of NASA as a labor force remain unexamined, however. Although the individual stories of astronauts, flight controllers, and rocket scientists have been recorded, the collective stories of the thousands of people who made particular space projects work offer many opportunities for thinking about the space agency as a workplace.[32]

Labor practices and environments, including the relationship of the space agency with contract work, a key characteristic of NASA's labor structure—and of the larger aerospace industry—remain an underdeveloped topic. For instance, the Grumman Corporation, the engineering company that won the

31. Eric Foner, ed., *The New American History* (Philadelphia: Temple University Press, 1990), p. vi.

32. Howard McCurdy, *Inside NASA: High Technology and Organizational Change in the U.S. Space Program* (Baltimore: Johns Hopkins, 1993). See also Diane Vaughan, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1996); Joseph J. Trento, *Prescription for Disaster: From the Glory of Apollo to the Betrayal of the Shuttle* (New York: Crown Publishers, Inc., 1987); Greg Klerkk, *Lost in Space: The Fall of NASA and the Dream of a New Space Age* (New York: Pantheon Books, 2004).

NASA contract to design and manufacture the Lunar Modules for the Apollo Program, never unionized because Grumman self-consciously promoted a sense of community at its facilities while discouraging labor organizing. In a very different example, engineers working at space work sites like the Jet Propulsion Laboratory came to understand that layoffs were a part of the business plan. Aerospace companies hired highly skilled workers when contracts began, only to dismiss them when contracts ended. These two stories are small pieces of a larger story about how shifting relationships between NASA, aerospace contractors, and the larger aerospace industry shaped and reshaped what it meant to do space work from the beginning of the Space Age through the end of the Cold War.[33] Finally, the labor history of the U.S. space program should also include the entire communities that grew up around NASA Centers, when long-term projects like Mercury, Gemini, or Apollo required entire families to relocate. The transformations of places like Huntsville, Alabama, or Cape Canaveral, Florida, or Tysons Corner, Virginia, illustrate how the work of science and technology industries transformed landscapes, creating new communities and cultures.[34]

If the labor history of space has only just begun to be explored, questions of race and ethnicity have been almost entirely ignored. Only one book has dealt with race or ethnicity as a primary topic. J. Alfred Phelps's collective biography, *They Had a Dream: The Story of African-American Astronauts*, offers chapter-length biographies of African American astronauts as basic compensatory history (adding omitted names and events to the historical record without a broader analysis of their social, political, or cultural contexts).[35] Such work is a necessary beginning, but much more remains to be done. Given the sophistication of the analysis in African American history, Asian American history, and Native American history, and the emergence of interest in whiteness as a constructed racial category, space history's lack of analysis of race betrays an unspoken but distinct discomfort. The aspect of the New Social History that has received the most attention in space history has been women's contributions. In recent years, there has been a sudden flurry of attention to women in space. In 1996, when I began my dissertation research on Randy Lovelace's Woman in Space Program, a short-lived and privately funded proj-

33. M. G. Lord, *Astro Turf: The Private Life of Rocket Science* (New York: Walker & Company, 2005). See also Joan Lisa Bromberg, *NASA and the Space Industry* (Baltimore: Johns Hopkins, 1999). Lord's memoir of her father's work at the Jet Propulsion Laboratory (JPL) offers useful insights into JPL as a workplace. Bromberg addresses NASA's relationship with contracting companies as a business history while calling for future scholars to return to this subject through primary research.

34. Paul Ceruzzi, *From Tysons Corner to Internet Alley: High Technology in Northern Virginia, 1945–2001* (New Brunswick, NJ: Rutgers University Press, forthcoming in 2006).

35. J. Alfred Phelps, *They Had a Dream: The Story of African-American Astronauts* (Novato, CA: Presidio, 1994).

ect that tested women pilots for astronaut fitness in the early 1960s, only two short pieces and a book chapter had been written about the subject.[36] By the time my book was published in 2004, however, it counted as the fourth major treatment of that specific program in six years.[37] In addition, three new books have recently been published documenting women's successes as astronauts and cosmonauts.[38] In all, there are seven new books published since 2002 about women and space.[39] Another dissertation about NASA's first women astronauts connects the question of women astronauts to the literature in the history of science and technology.[40]

This attention reflects the increased visibility of women in the astronaut corps, the most visible face of NASA's programs. Yet, despite the attention to the subject, space history can still only be considered as working in relation to women's history but not in any real dialogue with women's history or women's studies. Most of the new accounts amount to compensatory history, adding women to the historical account with little attempt to contextualize the histories by using them to make a broader critique or reassessment of the time in which they are set. And little to no work has offered a critical analysis of the role of gender (both femininity and masculinity) in a particular time or place. Investigating the treatment of women can expand what is known about the complex, intersecting, social, cultural, and political contexts of the U.S. space program.

A partial solution for development in the neglected areas may lie in a subfield that has a long relationship with space history: oral history. Oral history continues to be a useful tool, technique, and intersecting subfield for space

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36. Joseph D. Atkinson and Jay M. Shafritz, "The First Efforts of Women and Minorities to Become Astronauts," chap. 5 in *The Real Stuff: A History of NASA's Astronaut Recruitment Program* (New York: Praeger, 1985); Sheryll Goecke Powers, *Women in Flight Research at NASA Dryden Flight Research Center from 1946 to 1995*, Monographs in Aerospace History, no. 6 (Washington, DC: NASA, 1997); Sylvia D. Fries, "The History of Women in NASA," NASA TM-108100, Women's Equality Day talk, Marshall Space Flight Center, 23 August 1991.

37. Leslie Haynesworth and David Toomey, *Amelia Earhart's Daughters: The Wild and Glorious Story of American Women Aviators from World War II to the Dawn of the Space* Age (New York: William Morrow & Co., 1998); Stephanie Nolen, *Promised the Moon: The Untold Story of the First Women in the Space Race* (New York: Four Walls Eight Windows, 2002); Martha Ackmann, *The Mercury 13: The Untold Story of Thirteen American Women and the Dream of Space Flight* (New York: Random House, 2003); Weitekamp, *Right Stuff, Wrong Sex*.

38. Pamela Freni, *Space for Women: A History of Women with the Right Stuff* (Santa Ana, CA: Seven Locks Press, 2002); Laura S. Woodmansee, *Women Astronauts* (Burlington, Ontario: Apogee Books, 2002); Bettyann Holtzmann Kevles, *Almost Heaven: The Story of Women in Space* (New York: Basic Books, 2003).

39. In addition to those listed above, see also Laura S. Woodmansee, *Women of Space: Cool Careers on the Final Frontier*, Apogee Books Space Series 38 (Burlington, Ontario: Collector's Guide Publishing Inc., 2003).

40. Amy Foster, "Sex in Space: The Politics and Logistics of Sexually Integrating NASA's Astronaut Corps" (Ph.D. diss., Auburn University, 2005).

historians. In 1996, NASA's Johnson Space Center History Office initiated an oral history project to interview NASA employees and contractors from the Mercury, Gemini, Apollo, and *Skylab* programs, as well as to convert decaying oral history reel-to-reel tapes to more stable media. An analysis and reflection on NASA's history and continuing work with oral history can be found in Roger Launius's 2003 article in a special issue of the *Oral History Review* about oral history in the federal government.[41] As we continue to lose the original participants in early space efforts, the need to preserve space history in comprehensive, well-researched, -documented, and -preserved interviews is becoming all the more important. Furthermore, the current scholarship in oral history demands consideration of what recorded interviews reveal about race, class, gender, status, and power. Perhaps a closer relationship between oral history and space history, two subdisciplines that have been closely linked for some time, could provide one avenue for the New Aerospace History to develop in its integration of the insights of the New Social History.

In 2000, Roger Launius identified a New Aerospace History that seeks to engage with the scholarship and insights of the New Social History. And, as just outlined, much remains to be done. But in many ways, the scholarly world has already moved beyond the ideas of the New Social History. If space history is going to engage with the insights provided by the explosion of historical scholarship in the last 20 years, space historians must begin to grapple with the influences of critical theory.

Critical Theory as a Toolbox

Critical theory is an umbrella term that encompasses the diverse and often divergent theoretical schools of structuralist, poststructuralist, feminist, Marxist, postmodern, and psychoanalytic theory that emerged since the 1970s in literary and anthropological analysis. Critical theory concerns itself with the differences between representations and reality and, in particular, the ways in which language constructs what is perceived. One part of this analysis is the complex social construction of various identities (race, class, gender, sexuality, etc.). Critical theory looks at how cultures and institutions construct some identities as privileged while marginalizing or denying others. (A similar dynamic also occurs on a national or international level, underlying colonialism and postcolonial relationships between states and peoples.) Critical theory questions the seeming obviousness of these categories, pointing out how assumptions about naturalness are part of the construction of privilege (and thus also of marginalization). The postmodern component of critical theory addresses globalization, consumerism, and the fragmentation

41. Launius, "We Can Lick Gravity."

of authority. Such scholarship often pursues discourse analysis, a study of how the way that a topic is discussed shapes its reality. Epistemological questions of how meaning is made and how we know what we know also drive this analysis. Critical theory thrives on juxtaposing texts (which include not only literal, written texts, but also any cultural form that can be read for meaning, including images, music, movies, or television). It embraces contradictions, often frustrating those who want definitive characterizations. In recent years, the exploration of these questions using critical theory has proven to be so fruitful that entire new research fields now exist, including cultural studies, queer theory, and critical race theory.

Historians began to engage literary theory in the late 1970s. In fact, by the time I entered graduate school in the early 1990s, there was a perceptible divide in the history department where I studied at Cornell University. On the one side, Dominic LaCapra led the School of Criticism and Theory, a summer institute begun in 1976 that brought together faculty and graduate students for an intensive six-week theory "boot camp" premised on the idea that an understanding of theory is fundamental to humanistic studies. On the other side, empiricists, including my adviser, taught the intensive study of primary documents—not as texts to be juxtaposed at will, but as evidence of the reality of the past.

The theorists argued that overarching concepts of hegemony, power, and privilege unlocked the central debates raised by the histories they analyzed. They embraced Foucault's suggestion that all history is really about the present, not the past, and that the "real" or "true" past was unknowable. They wrote comfortably for a scholarly audience, preferring analysis to narrative (which is all constructed anyway). The empiricists lamented the impenetrability of theoretical jargon and the ahistorical problems of bringing the postmodern European theory of Foucault to bear on czarist Russia, colonial Latin America, or premodern China. They believed that sufficient research could reveal a past that might not be objectively perceived but that was nonetheless real. They believed in the power of history as a tale well told, in the tradition of the scholar-writer. As I did with the radio caller mentioned at the beginning of this piece, I find that I resist fitting neatly into one category or the other. Although I completed my Ph.D. as a broadly trained Americanist rooted in empirical research, my first job—teaching women's studies, a very theory-centered field—became an informal three-year postdoc in critical theory.

Space history, of course, fits both camps. On the one hand, the history of spaceflight can easily be told as a modernist narrative of progress achieved through rationality and hierarchy. For that matter, space history also fits well into American exceptionalism, the model of U.S. history as an example for the world. On the other hand, critical theory also applies. National and international space efforts cannot be understood without consideration of the mass media, mass consumption, and the mass production that feeds it. Globalization is also a crucial context for space history.

Indeed, the very topic of this essay, an analysis of the historiography of space history and its relationship with the other history subdisciplines, follows an epistemological line of inquiry. It seeks to illuminate critical issues in the history of spaceflight through an analysis of how the field of space history has been constructed and what other fields have been influencing the questions asked—at base, investigating how we do what we do, to the end of understanding how we know what we know. Over the last 10 years, critical theory has become an entrenched part of scholarly discourse, enabling useful critiques of power and difference that bridge national and international studies and bring race, gender, and class into the center of political and social analyses.

For those interested in space history, analyzing the broader cultural settings provides a new way to understand how space efforts resonated. Two examples help make the point. In her 1998 book *Aliens in America*, Jodi Dean analyzed the pre-Y2K fascination with aliens and UFOs as a part of the 1990s trend of interest in space-themed things. Dean suggests that Ron Howard's 1995 film *Apollo 13* transformed the story of a 1970 space accident into a tale that reflected 1990s American preoccupations with a safe return to home that is witnessed through television. Likewise, British scholar Debra Shaw analyzed the spacesuit as cultural icon in the context of broader American popular culture. In both cases, the authors used space as part of their analyses, but neither author is particularly interested in actual spaceflight. A wonderful opportunity exists here for a scholar to work on the cultural imagery of space while also taking spaceflight seriously as something real, not merely as a convenient text.[42]

One of the best examples of a scholar executing sophisticated theoretical analyses in plain language while taking spaceflight seriously is Constance Penley's analysis of NASA in the first half of her book *NASA/TREK*. Written in the wake of the Space Shuttle *Challenger*'s January 1986 explosion, media studies scholar and cultural critic Penley addressed the public's fixation on Christa McAuliffe, the "ordinary citizen"/teacher whose inclusion on the flight accounted for the intense media coverage of the much-postponed launch. Her analysis revealed how widely circulated sick jokes about the public deaths of the Shuttle astronauts betrayed cultural discomfort with women's presence in the highly technological Space Shuttle. Penley's arguments are carefully made and easy to read even as they draw on a vast literature in feminist theory. Penley moves beyond a simple accounting of women's or men's roles

42. Jodi Dean, *Aliens in America: Conspiracy Cultures From Outerspace to Cyberspace* (Ithaca, NY: Cornell University Press, 1998); Debra Benita Shaw, "Bodies Out of This World: The Space Suit as Cultural Icon," *Science as Culture* 13, no. 1 (March 2004): 123–144.

to consider how ideas about gender are embedded in customs, organizational structures, and social practices.[43]

The construction of masculinity is just as important as the construction of femininity. In *Astro Turf*, her memoir of her father, a 1960s Jet Propulsion Laboratory engineer, M. G. Lord's deeply personal story also offers a model for a nuanced analysis of the constructions of gender at NASA Centers. Lord explores the rocket engineer as an archetype of 1960s masculinity, a stereotype which she acknowledges "no human person can ever fully embody. The buzz-cut cowboys of Mission Control, homogenous as a Rockette kick-line, were a cold-war fiction, along the lines of other cold-war fictions—the notion, for instance, that hard-drinking, womanizing test pilots, when selected to be astronauts, metamorphosed into temperate family men." Lord's reflections demonstrate that a monolithic masculinity did not exist. Rather, different archetypes of masculinity existed in flight control, or planetary probe engineering, or the astronaut corps: constructions of masculinity that were specific not only to a particular time and place, but also to different jobs. More so, she illustrates in easily comprehensible prose how abstract constructions of masculinity had real effects even though individual men did not conform to the stereotypes.[44]

Analyses of masculinity are also being developed in histories of the images of astronauts. Roger Launius's ongoing reevaluation of the Apollo astronauts in myth and memory offers an insightful analysis of the men's personal backgrounds. With only one exception, NASA's Apollo astronauts were working-class or middle-class men who benefited from military service and the GI Bill—a story that mirrored the postwar American dream, the ideal of the best that America had to offer. The cultural story told by Apollo's models of masculinity provides a marked contrast with the characterizations observed when the nation mourned the *Columbia* astronauts. In that case, the reaction to the *Columbia* tragedy represented a little-noticed but significant shift in the way that astronauts have been depicted. More than just the absence of the previously disproportionate attention to the female members of the crew (as Penley noted after the *Challenger* disaster), the aftermath of the *Columbia* loss included a noticeable focus on the male astronauts as husbands and fathers. The *Columbia* coverage revealed a new conceptualization of men as active, nurturing parents, not just as "family men" (a term that describes a kind of dependability that serves as a workplace asset but which said little about a man's real role as an integral part of his family's life). In both examples, the images of the astronauts reflect the cultural context in which they lived.[45]

43. Constance Penley, *NASA/TREK: Popular Science and Sex in America* (New York: Verso, 1997).

44. M. G. Lord, *Astro Turf*, p. 16.

45. Roger D. Launius, "Heroes in a Vacuum: The Apollo Astronaut as Cultural Icon" (presented at the Organization of American Historians 2005 Annual Meeting, San Jose, CA, 3 April 2005);

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A practical model for this kind of wide-ranging gender analysis can also be found in some recent work in diplomatic history. Frank Costigliola's close reading of George Kennan's famous long telegram advocating containment noticed that Kennan cast the Soviet Union and the United States in gender-laden metaphors. Costigliola argues that Kennan's appeal to cultural ideas about proper gender roles reinforced his arguments about necessary U.S. action. Likewise, Robert Dean offers a very useful analysis of the particular brand of upper-class, White masculinity that defined and drove John F. Kennedy and his New Frontiersmen. Examining White House decision-makers throughout the 1960s, Dean points out how gendered metaphors of strength and weakness underlay foreign policy-makers' understanding of international situations, specifically the Cold War. Dean shows how the gendered metaphors used to understand foreign policy led to real Cold War decisions, bringing ideas about gender into crucial national actions. In both cases, gender does not mean "women" but rather the social construction of both masculinity and femininity.[46]

In much the same way, critical race theory has demonstrated that race also requires a more complex treatment than the oversimplified American preoccupation with rigid Black/White racial categories. Critical race theory demonstrates that race is mutable, not biologically determined, and yet nonetheless real. Because race categories have been historically constructed and carried (and still carry) real consequences for people of all colors, the construction of those categories and what they meant at a particular place and time provide the best way to analyze their historical influence and multiple meanings.

The best examples of this kind of work are being carried out in cultural studies. In *Astrofuturism: Science, Race, and Visions of Utopia in Space*, De Witt Douglas Kilgore employs well-grounded race analysis as a part of his examination of the connections between space science fiction and utopian visions of the future set in space. Another author analyzing race in space-themed popular culture is Daniel Bernardi, whose work on *Star Trek* investigates how America's obsession with race played out in the multiple incarnations of Gene Roddenberry's cult hit television show and its many spin-offs. For Bernardi, "'race' refers to a multifaceted, omnipresent but utterly historical category of meanings." How these meanings are constructed in particular times and places

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Margaret A. Weitekamp, "Mourning Men and Women: Gender in the Coverage of the Space Shuttle Columbia Accident and Other Space Tragedies" (presented at the Organization of American Historians 2005 Annual Meeting, San Jose, CA, 3 April 2005).

46. Frank Costigliola, "'Unceasing Pressure for Penetration': Gender, Pathology, and Emotion in George Kennan's Formation of the Cold War," *Journal of American History* 83, no. 4 (March 1997); Robert D. Dean, *Imperial Brotherhood: Gender and the Making of Cold War Foreign Policy* (Amherst: University of Massachusetts Press, 2003).

informs his work, allowing his analysis to account for changes in race relations over time. As a result, Bernardi's work avoids reinforcing racial categories.[47]

Having more complex, theoretically grounded conceptions of race also allows scholars to examine the social and historical construction of whiteness. In addition to the historians documenting the contested construction of White racial identity in the United States, other scholars have been exploring the impact of White privilege: the unearned and usually unnoticed advantages that accompany being White in America. For space history, an awareness of whiteness as a contested identity, which carried real meaning for people's day-to-day lives, opens new topics for investigation. For instance, it would be very interesting to examine a place like Huntsville, Alabama, where whiteness took on several different historical meanings. By the 1950s, the Army Ballistic Missile Agency in Huntsville welcomed German rocket scientists, who had been brought into the U.S. through Project Paperclip. These men found themselves living and working in a state just beginning to wrestle with the fundamental questions raised by the Civil Rights movement. Little race history presents itself to be written when the focus remains narrowed to documenting the historical presence of African American workers. But if one considers the multiple and varied meanings of whiteness, this history offers intriguing possibilities for reinvestigating a formative site for space history.[48]

One of the reasons that space history has not always embraced all of the aspects of the New Social History is that many scholars dismiss the focus on race, class, ethnicity, and gender as forced or unnecessary due to the lack of women or minorities in a field. The previously ignored women's stories have been largely uncovered and already told, the argument goes. Having few people of color working in various space programs means that little race history presents itself to be written. Few labor problems beg for a class history analysis. But when considering critical theory, the question becomes, not how does one write an appropriately attentive history of each race or ethnicity, but rather, how did the space program deal with race or ethnicity? Not where are the women, but how did the space program deal with gender for both men and women? Not where are the gays, but why is the space program so relentlessly straight (and, for that matter, so reluctant to broach the topic of sexuality at all)?

Such questions are relevant even if the identities being analyzed were not noticed or commented upon at the time. Indeed, one of the defining

47. De Witt Douglas Kilgore, *Astrofuturism: Science, Race, and Visions of Utopia in Space* (Philadelphia: University of Pennsylvania Press, 2003); Daniel Leonard Bernardi, Star Trek *and History: Race-ing Toward a White Future* (New Brunswick, NJ: Rutgers University Press, 1998), p. 15.

48. Matthew Frye Jacobson, *Whiteness of a Different Color: European Immigrants and the Alchemy of Race* (Cambridge, MA: Harvard University Press, 1999); Peggy McIntosh, "White Privilege: Unpacking the Invisible Knapsack," in *Women: Images & Realities, A Multicultural Anthology*, ed. Amy Kesselman, Lily D. McNair, and Nancy Schniedewind, 3rd ed. (New York: McGraw-Hill, 2003), pp. 424–427.

Dr. Wernher von Braun greeting a crowd at the Gulf South State Fair in Picayune, Mississippi, in October 1963. *(NASA photo no. GPN-2000-000538)*

characteristics of privilege is obliviousness. White privilege, for instance, includes the assumption of whiteness as the norm, a condition that does not need to be named (in contrast to the way that Blackness, for instance, does not go unnamed). Even though participants did not comment on the impact of whiteness or masculinity in the historical moment, the contemporary social construction of those identities continued to shape historical actors' experiences. The insight that all history contains gender, race, ethnicity, and class opens up new possibilities for integrating these elements into the ongoing discussions of technologies and politics in any space history.

One of the admitted drawbacks of critical theory is the jargon that accompanies it. As one teaching Web site suggests, "The hardest part of understanding and working with critical theory is grasping and using the new vocabulary, but, as with all languages, the new vocabulary will empower you and enhance your exposition of already existing thoughts and ideas."[49] I disagree. The concepts and insights of critical theory empower scholars. The vocabulary can be cumbersome and obfuscating. The examples offered above, however, demonstrate that critical theory can be employed in the service of an historical analysis while still using plain language. Keeping in mind the importance of narrative and craft in the writing of history will allow space historians to integrate these insights into readable histories. Critical theory does not offer all of the answers for the development of space history, but sampling from this toolbox can move the field forward.

49. Dino Felluga, "General Introduction to the Site," *Introductory Guide to Critical Theory*, updated 28 November 2003, *http://www.purdue.edu/guidetotheory/introduction/* (accessed 16 February 2005).

Chapter 17

Space Artifacts: Are They Historical Evidence?

David A. DeVorkin

Museum collections . . . show you not what there was but what was collected.

—Jim Bennett, "Scientific Instruments," in *Research Methods Guide*, Department of History and Philosophy of Science, University of Cambridge

Anyone sensitive to the immense costs involved in collecting and preserving the material legacy of modern culture must question such expenditures at one time or another. Can the needs of history, for instance, justify the effort and expense it takes to identify, acquire, transport, preserve, inventory, evaluate, and possibly even to exhibit some object of note? An 11th-century astrolabe, a Galilean telescope, or the fabulously mysterious and insightful Antikythera mechanism all, no doubt, have provided valuable insight into historic events, capabilities, unwritten norms of practice, and cultural imperatives. But what of the modern stuff, essentially the past 50 years of the Space Age? What does the *Freedom* 7 capsule tell us? Or what can Apollo 11, or Armstrong's chronograph, or the backup mirror to the Hubble Space Telescope tell us that other forms of documentation cannot reveal? Why collect and preserve material artifacts of the Space Age when there is, indeed, a mountain of documentation readily accessible that can tell us everything we might possibly want to know or can answer every question we can imagine to ask?

The act of collecting and properly preserving objects that somehow represent or inform the history of the exploration of outer space is one of the most expensive and labor-intensive ways of preserving the record of space history. As an historical activity, it is far more expensive, requiring a broad range of talents and expertise and an infrastructure at least an order of magnitude greater than that required for any library or archival facility devoted to space history, and it is many orders of magnitude greater than what is required by an individual scholar to pursue publishable space history. Why, then, do institutions and historians engage in such activity? Are the payoffs and returns proportionally worth the effort and expense? Can the payoffs be measured on scales that compare to the professional payoffs resulting from other forms of historical inquiry and outreach, or are the payoffs of a wholly different character, so removed or distinct from familiar intellectual processes and modes of communication that they demand a distinct scale for evaluation separate from, or complementary to, those in place within academe? This essay will raise these questions and explore them.

WHY ARTIFACTS ARE MARGINALIZED AS HISTORICAL EVIDENCE

In a 1962 essay in *Science*, filled with the exuberance of establishing a new discipline, Mel Kranzberg argued that there were ample reasons to support the history of science and technology disciplines as the "'newest' history."[1] Speaking more about technology than science, the newest history, he argued, offered promise of reconnecting the two cultures, as if to counter C. P. Snow's allegations. As Kranzberg wished to describe it, "It is about human work [in science and technology] . . . . Indeed, the search for truth and order and beauty in science is comparable to the same striving in literature, art, poetry." It is a very human activity to search for truth, order, and beauty, and the nature of the search reflects changing intellectual climates, human inventiveness and imagination, and human values and social systems. Technology plays an intimate part in all of this because its significance "lies in what it does." Again, following Kranzberg, "the significance of technology is in its use by human beings."[2]

In his 1962 essay, he explored the significance of the study of the history of science and technology, and its possible applications, and identified typical questions modern practitioners of the "newest history" ask and how the exploration of their answers might benefit society. Above all, Kranzberg placed humans at the center of attention as well as the institutions they build and the nations they defend. He used the telephone to describe what is important about technology: At one level, the telephone is merely a system of wires, circuits, and switches, transmitters and receivers of electrical signals. Issues historians have addressed have included who invented it and why they did it, motivations, resources available, assumptions, "but the human meaning of the telephone lies in its transmission of sound for long distances between persons." The telephone has changed the way people live their lives and communicate

1. Melvin Kranzberg, "The Newest History: Science and Technology," *Science* 136, no. 3515 (11 May 1962): 465.
2. Ibid., p. 466.

with others. Using the telephone and other examples, Kranzberg's message is "that science and technology have social consequences."[3]

Kranzberg's article, at one level, reflects modern practice. It leaves the strong impression that the "things" of technology do not constitute the knowledge base, but that they do represent history in some amorphous way. Indeed, in his campaign to increase attention by historians and scientists to the value of the history of science and technology, he emphasized its social application and minimized issues relating to what one might call a "material culture" focus. "Things" do appear prominently, and Kranzberg is clearly sensitive to the ills of Neoplatonic aristocratic dualism, the emphasis of brain over hand. But for the sake of his argument in 1962, things merely symbolize human goals and aspirations and adorn the titles, texts, and images of the literature of the history of science and technology.

Thus, in the 40-odd years since Kranzberg's essay in *Science*, an unintended consequence of his campaign, and of those of his generation, was a certain neglect of the things of science and technology, the material artifacts, as sources of information themselves. They could be sacralized and celebrated and even revered, but they did not, in and of themselves, provide a knowledge base. And as a new literature emerged in the history and technology of space exploration, a consequence of the increased interest in the field overall since Sputnik, it also reflected the same priorities of the newest history and did not include things in its formal knowledge base.

Things do matter in the geological and biological sciences, as well as in the broader ranges of natural history including anthropology, archaeology, and paleontology. Collections do constitute primary knowledge. After all, these disciplines largely grew up around collections that had to be organized and preserved somehow, and the present structure of these museums and their collections still represents the organized data the scientist needs.[4] But for the disciplines engaged in space history, where we might find historians of technology and science, or social and cultural history, military history, business history, American history, American studies, along with a smattering of sociologists, economists, policy specialists, and psychologists, to say nothing of those who came from backgrounds in aerospace itself, none of these areas of inquiry grew up around a practice of collecting artifacts, organizing and classifying them, and searching for new knowledge in the effort, through empirical analysis or some form of rational argument. As a result, although those engaged in curatorial functions most definitely think about their collections and treat them to all the standards required of their codes of ethics and institutional capabilities, few of them actually have utilized these collections as

3. Ibid., p. 466.
4. Bernard S. Finn, "The Science Museum Today," *Technology and Culture* 6, no. 1 (1965): 78–79.

primary evidence in their historical research and writings. Many have written about their collections and the objects in them, of course, ordering them by age, manufacturer, speed, function, and capability, because they are fascinated by or are somehow attracted to objects, but the data they employ are of the more traditional kind: the written and spoken word, images, pictorial representations, and the like.[5]

To make this last observation, Joseph Corn surveyed a decade's worth of articles in *Technology and Culture*, the quarterly publication of the Society for the History of Technology. He found that less than 15 percent of the authors "employed any material evidence" and, of these, most wrote on ancient or early modern technologies. "Rhetoric to the contrary, then, the history of technology as a field is not deeply committed to learning from things."[6] Corn takes this farther to identify factors that detract from the use of things as evidence and also argues that because of these social factors limiting how historians communicate processes and the influences upon them, in fact, the survival of the real thing (the true artifact and even the facsimile) is more important than one might appreciate from the published record alone.

Things as "Congealed Culture"

After all, things do exist, have existed, and are constantly on the minds of at least some historians, especially those who find themselves working in museums or training those who might see museums as a career goal. Things constitute the "corpse" of much of what we call science and technology, and so they have been regarded by some as holding out potential as a source of diagnostic or even forensic knowledge offering insights unavailable otherwise. Given the emphasis on people and institutions fostered by Kranzberg and almost all subsequent workers, this potential has remained largely locked up in the things themselves, which has led at least one prominent historian of technology, Thomas Parke Hughes, to refer to them as "congealed culture."[7]

Hughes's rhetorical concept has been applied by scholars to various and sundry objects, institutions, and individuals, mainly to describe a static relic or an art object, "a kind of tomb for the creative spirit" that has somehow been transported into a context wholly unlike that of its creation: the art gallery, living room, museum, or historic site. The term has also been used to

5. Joseph J. Corn, "Object Lessons/Object Myths? What Historians of Technology Learn from Things," in *Learning from Things, Method and Theory of Material Culture Studies*, ed. W. David Kingery (Washington, DC: Smithsonian Institution Press, 1996), pp. 35–54.

6. Ibid., p. 37.

7. Thomas Hughes, commentary in Pamela Mack and David DeVorkin, "Proseminar in Space History," *Technology and Culture* 23 (1982): 202–206.

encapsulate entrenched personalities, hopelessly outdated or resistive bureaucracies, and static libraries and the books they contain.[8] Hughes, however, had no such negative thoughts in mind when he used the term at a May 1981 "Proseminar in Space History" at the National Air and Space Museum. There, he was expressing his feeling that it was the best we could hope for in material culture, but to utilize it we had to learn how to obtain the proper tools to capture the essence of an artifact and to understand how it represents an amalgam of interests, motivations, ideas, questions, and techniques that are representative of the culture that conceived of it, paid for it, built it, and used it. At least, that is what some participants took away from his commentary.[9] Hughes's remark embodied the perennial challenge facing curators of objects, or things, to find ways to unpack all the forces and drives that brought that artifact into existence and played a part in its lifetime of use. Curators trained as historians have certainly done much of this. The literature of space history is rich in the study of the technologies and the objects representing them that made space travel possible. But the question in my mind then and now is, where is the survival of the artifact itself in all this effort? And what is its role in history: as historical evidence leading to new knowledge, or as a commodity, an ornament that somehow illustrates or celebrates, but does not necessarily inform the past?

Kranzberg's assertion that the history of technology focuses on human actions did not prevent almost half of the articles in *Technology and Culture* scanned by Corn from dealing somehow with devices: tools, weapons, instruments, objects with a function. But historical studies of things are subject to a wide variety of perspective: "What's nuts and bolts to one historian is 'congealed culture' to another," Larry Owens once observed, implying that things can be described in terms of their "brute facts" of existence, to excruciating detail, but they also "embody conceptual schemes and logical strategies for dealing with the world." The historian's task, ideally, is to employ interpretive and descriptive tools that present an integrated portrait of the machine/object/thing and the ideas and aspirations it embodies. Owens's very definition of a good historian [of technology] was someone with sensitivity to "socioeconomic and institutional environments."[10]

8. John S. Duffield, "Political Culture and State Behavior: Why Germany Confounds Neorealism," *International Organization* 53 (1999): 765–803, noting Jepperson and Swidler describing institutions as "congealed" culture; John D. Kelly, "Nature, Natives, and Nations: Glorification and Asymmetries in Museum Representation, Fiji and Hawaii," *Ethnos* 65, no. 2 (1 July 2000): 195–216; Shaun Gray, quoted in "Aesthetics of Computer Graphics," *pixxelpoint*, *http://www.pixxelpoint.org/2001/article-01.html*.

9. Discussions with Pamela Mack over the years.

10. Larry Owens, "Book Review," *Isis* 78 (1987): 625–626 (review of Michael R. Williams, *A History of Computing Technology* [Englewood Cliffs, NJ: Prentice-Hall, 1985]).

A machine can certainly embody ideas and assumptions. First, implicit in its design are ideas about the way nature works, as well as assumptions of the ways humans work, as well as assumptions about how a particular human goal can be met. Take the telescope: it definitely embodies basic assumptions about how nature works. Although invented before systematic rules in geometrical optics provided guidance, empirical or experimental exploration soon showed how to build telescopes with greater magnification, resolution, and light-gathering power. Following the development of astronomical telescope technology, then, how it changed over time, has the potential of revealing how technical limitations, intellectual drives, and social issues influenced the development of each of these powers or inhibited their growth for one reason or another. Yet, with but few exceptions, histories of telescope technology in the past tended not to be organized this way and instead were chronological and periodized, or centered on observatory development. And with even fewer exceptions, mainly the work of Albert van Helden and others noted below, histories of telescope technologies have not required the survival of the telescopes themselves. Yet telescopes are lovingly preserved and beautifully displayed throughout European culture as an enduring legacy of human achievement and curiosity. Faced with this situation, any curator of things must, at some point in life, pause and ask, "Why?"

This essay, then, is an exploration of these questions: Is the existence of an artifact useful to history, or does its value reside elsewhere? Is there a sensible difference, in researching and writing history, having the actual artifact involved in that history at hand or not? We will begin by looking at institutional rationales for collecting, then at individual arguments, and finally we will sum up by suggesting some alternative ways to justify the effort.

Addressing the Issue: Rationales for Collecting

It is surprising that there doesn't appear to be a literature critical of the act of formal collecting. There is a literature defending and rationalizing collecting and a smaller literature looking into the psychological motives that stimulate collecting on both individual and collective bases, but there appears not to be one questioning the value or importance of collecting. Of course, I raise this as an observation in the hopes that a reader who has read more widely than I have at this point will offer a correction and direct me to what I have missed. Until that happens, however, I will labor under the assumption that collecting is a core act of human culture, bound up some way in a search for identity and even for power and transcendence.[11] But I will also

11. Werner Muensterberger, *Collecting: An Unruly Passion* (Princeton, NJ: Princeton University Press, 1994).

accept the possibility that formal collecting, by institutions and nations, is a self-conscious act that in and of itself is artificial enough to warrant rationalization. Therefore, we should begin by looking at the rationalizations people and organizations have given for collecting.

Institutions and organizations are, first and foremost, composed of individuals, and these individuals act singly and collectively out of both personal and professional motivations. Personal motivations to collect derive from a wide variety of impulses and drives: collecting can provide a sense of identity, personal exploration, security and validation, self-worth, transcendence, and power. All manner of people collect all imaginable things, from stamps, coins, and baseball cards to M&M items, cars, telescopes, and phonograph records.[12] It is one of our more basic instincts and seems to be shared among many cultures. Styles vary, of course, from astute collectors to indiscriminate hoarders. Individuals rarely rationalize why they collect, nor do they need to. But institutions, especially public ones or those existing on private or corporate philanthropy, typically try to, because of the costs involved.

Historians, museum professionals, anthropologists, geologists, biologists, collectors of all types, and their institutions have presented numerous and varied arguments for preservation. In the cultural arena, possibly the most pervasive effort was established by the National Park Service emerging from the Historic Sites Act of 1935: "To preserve places of national significance that retain exceptional value as commemorating or illustrating the history of the United States for the inspiration and benefit of the people."[13] The 1946 enabling legislation that ultimately gave life to the National Air and Space Museum in 1976, which we always cite in the various editions of the introduction to our "Collections Rationale," calls upon us to "memorialize the national development of aviation and space flight." Our charge is to "serve as the repository for, preserve, and display aeronautical and space flight equipment and data of historical interest and significance to the progress of aviation and space flight, and provide educational material for the historical study of aviation and space flight and their technologies."[14]

In order to carry out its designated task, the Park Service has mounted numerous "theme studies" and has created a standardized "National Register

12. Ibid.; Igor Kopytoff, "The Cultural Biography of Things: Commoditization as Process," in *The Social Life of Things: Commodities in Cultural Perspective*, ed. Arjun Appadurai (Cambridge: Cambridge University Press, 1986), pp. 64–91; Frederick Kunkle, "A Heart Melts at Sight of All Things M&M's," *Washington Post* (10 February 2005): Montgomery Extra, pp. 16–17.

13. National Historic Landmarks Survey, "Surveying American History," June 2003, *http://www.cr.nps.gov/nhl/*, p. 1 (accessed 10 February 2005).

14. Public Law 79-722, chap. 955, 70th Cong., 2nd sess., 12 August 1946. "Initially the legislation did not mention 'space,' but this was added and now serves as basis for the Museum's Mission Statement, as promulgated July 29, 1996," according to the Division of Space History, "Collections Rationale," 2005, NASM Curatorial Files, Washington, DC.

Nomination Form" that contains room for not only describing the candidate, but for including a narrative statement of historical, cultural, and architectural significance and how these characteristics meet a set of criteria maintained by the NPS. Reproduced in full, it reads:

> The quality of significance in American history, architecture, archeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and:
>
> A. That are associated with events that have made a significant contribution to the broad patterns of our history; or
>
> B. That are associated with the lives of significant persons in or past; or
>
> C. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
>
> D. That have yielded or may be likely to yield, [*sic*] information important in history or prehistory.[15]

Commemorating, validating, and illuminating historical events, lives of note, or objects of construction or manufacture within their original environments is thus the domain of an agency concerned with such diverse issues as land use and national identity. An entity of the Department of the Interior, it promotes programs in public recreation and education, with preservation at its core: more than half of the parks represent land management "set aside as symbols and evidence of our history and prehistory."[16]

The process followed by curators at the National Air and Space Museum is somewhat different than the National Park Service, though many of its criteria map onto those of the NPS. Symbolism and national identity pervade the collection. Although collecting activity ranges over the whole of the 20th century, collecting in space history itself was heavily augmented

15. National Register Bulletin, "How to Apply the National Register Criteria for Evaluation," *National Register Publications*, *http://www.cr.nps.gov/nr/publications/bulletins/nrb15/nrb15_2.htm* (accessed 10 February 2005).

16. "History," National Park Service Web site, *http://www.cr.nps.gov/history/hisnps/* (accessed 10 February 2005).

by an agreement between NASA and the Smithsonian set out in 1967 and modified on numerous occasions. This special agreement was set up because NASA realized that it was rapidly becoming responsible for "a growing number of artifacts, many with great historical value and others with great value for educational, exhibition, and other purposes, relating to the development, demonstration, and application of aeronautical and astronautical science and technology of flight."[17]

NASA decided that the Smithsonian was a more appropriate place to take on this responsibility since NASA did not really want to be in the business of managing a large collection of iconic objects that attracted wide public and political attention. Further, it sought out both a political buffer and a means of historical validation. Left unsaid but implicit in the act of agreement was the fact that in making this arrangement, the Smithsonian was also tacitly agreeing to a formal method of removing objects from the commodity sphere (commercial trading and speculation in space artifacts) and placing them into a singularized and sacralized sphere, to adopt (for the moment) the notions and rhetoric of the economic anthropologist. If one views the NASA/NASM Transfer Agreement as a cultural act from this perspective, one can see it as an example of culture counteracting commoditization (in fact, curators in the department have made this point repeatedly)—since the essence of culture is discrimination, and societies typically set aside or set apart certain objects they deem to be sacred. Anthropology teaches us that culture demands that certain things be singular, unexchangeable, and "publicly precluded from being commoditized."[18] Typically, such constraints are imposed by the state, seeking to create a symbolic inventory akin to the crown jewels of monarchies and reflecting the power of the state itself. National museums, then, can be likened to agencies of the state and mechanisms through which the state imposes its eminent domain to sacralize particular objects. To my knowledge, however, no other federal agency has this form of continuing formal agreement with the Smithsonian. Therefore, the existence of the act itself defines NASA as a unique cultural entity, and it would be useful if, sometime in the future, someone examined the agreement in that light.

This agreement, however, does not compel the Smithsonian to collect a NASA object but gives it first right of refusal. In addition, this arrangement does not limit the Smithsonian's interest to collecting NASA artifacts, since significant programs exist elsewhere within our culture and our focus is space history, not NASA history. Our department has thus identified issues of

17. "Agreement Between the National Aeronautics and Space Administration and the Smithsonian Institution Concerning the Custody and Management of NASA Historical Artifacts," signed 10 March 1967, in the introduction to Division of Space History's "Collections Rationale," 2005.

18. Kopytoff, "Cultural Biography of Things," p. 73.

concern when evaluating any object for inclusion in the national collection, independent of national origin or the part of the government, academe, or industry responsible for it. These are placed within a context that we hope and expect will somehow illuminate and inform space history generally. Choices are made based upon

1. the unique qualities of [the object]
2. the relationship of flown items to engineering prototypes, backups, and models
3. the place for ground support equipment such as simulators, operational consoles, test stands, and the like, and
4. the different metrics of culture, history, and technology that come into play when assessing the historical value of a space artifact.[19]

Within the agreement set forth by the two agencies, one also finds rhetoric describing what should be collected, again offering some guidance on how and why, and overall it attests to NASA's view that these objects possess cultural and educational, as well as technical, value. We maintain no other agreement with any other agency or institution in this country or with any nation. However, although there is a tacit understanding that the criteria we utilize to collect any object remain independent of the originating institution, our special agreement with NASA creates an institutional bias that we cannot and should not ever forget or ignore. The quotation from Jim Bennett at the outset of this paper should always be kept in mind: that collections represent choices made and therefore should not be construed as history but as part of history.

Thus far, looking at the rhetoric of these two very different collecting agencies, NASM and the Park Service, one finds consistent appeal to the need to memorialize, display, educate, or stimulate. These goals are presumed by museum professionals and, again, are the results of choices, both individual and collective. Even though these choices are socially conditioned, one can easily find in the rhetoric of museology a presumption of warrant: the International Council of Museums offers, for instance, a "Code of Ethics" for museums that identifies their collective purpose and their unique responsibilities.[20] Excerpting relevant elements, we find that according to ICOM, "Museums preserve, interpret and promote the natural and cultural inheri-

19. "Preface," Division of Space History, "Collections Rationale," 2005.

20. ICOM, "ICOM Code of Ethics for Museums," 2004, *http://icom.museum/ethics.html* (accessed 20 February 2005).

tance of humanity" and hold their collections "in trust for the benefit of society and its development." Museums are, in effect, social institutions that exist to "acquire, preserve and promote their collections as a contribution to safeguarding the natural, cultural and scientific heritage." ICOM sees these collections as a "significant public inheritance" that must be protected by law and international legislation. Throughout its ethics statement, there is a strong and explicit sense of stewardship "that includes rightful ownership, permanence, documentation, accessibility and responsible disposal."

Central to ICOM's warrant is that "museums hold primary evidence for establishing and furthering knowledge." Professional staff within museums are responsible not only for collections care and public accessibility, but for the interpretation of the collection as "primary evidence." Indeed, the notion of "primary evidence" stands at the very core of ICOM's ethics statement. ICOM, which represents all types of museums, including art, technology, and the natural sciences, asserts without example or citation that what museums collect constitutes primary evidence. It recognizes that the designation of primary evidence should not be "governed by current intellectual trends or museum usage" and offers out hope that primary evidence will be used to make a "contribution to knowledge that it would be in the public interest to preserve." Thus, according to ICOM, museums should regard collections as both a present and a future potential resource for knowledge production. The overall policy of the Smithsonian Institution reflects this sensibility, reaffirmed by its Board of Regents in 2001: "Collections serve as an intellectual base for scholarship, discovery, exhibition, and education."[21]

From the standpoint of the collecting institution, then, whose statements are largely bureaucratic and organizational, to say nothing of being self-serving, one finds arguments that still presume the value of collecting, rather than demonstrate value. Once again, it would be easy to reinterpret ICOM's assertions using the perspective of the economic anthropologist: "Power often asserts itself symbolically precisely by insisting on its right to singularize an object, or a set or class of objects."[22] Taken together with ICOM's view, these two interpretations offer copious evidence for rationalizing why we collect.

Each assumes that collections will be useful to "memorialize" or to "educate" and "inform" and even to "inspire." Each also assumes that collections constitute "primary evidence" for historical and scientific inquiry. Indeed, the economic anthropologist goes to considerable and quite convincing lengths to

21. Board of Regents, "Smithsonian Collections Management Guidelines," SD-600, 26 October 2001, p. 37.

22. Kopytoff, "Cultural Biography of Things," p. 73. Sometimes that power is tested. When a National Park Service theme study promised to designate a number of observatories as potential candidates for landmark status, observatory directors objected, fearing that such a designation would limit their power to modify their equipment and buildings. Landmark status was not conferred.

argue how a biography of a thing reveals new knowledge about culture. One can learn a lot, for instance, about inheritance rules and practices, as well as family structure, by following how a particular object moved through a family down through the generations. The biography of a thing, therefore, is not only contained in its production, but in its use and treatment as a commodity, and if that thing is somehow removed from the world of commerce and deified as a sacred object, its biography needs somehow to be preserved and made accessible in order for it to illuminate the culture involved.[23] Historians acting as curators might see this as a new way to appreciate the importance of the "provenance" of an object, the history of who owned the object and the conditions of transfer from one hand to another. But few, to my knowledge, have knowingly explored how provenance informs us about the overall culture—its values, priorities, and stability—within which the object moved. Economic anthropologists have long used these techniques to map out change among generations. Historians might take a cue from this and look for ways to apply provenance.

WHY PRESERVE OBJECTS? THE VIEWS AND ACTIONS OF INDIVIDUALS

In his survey of a decade's worth of articles in the journal *Technology and Culture*, Joseph Corn also identified ways that a few historians used objects as primary evidence, showing that indeed there is potential knowledge if the right questions are asked. He points to five different ways scholars have used objects as primary source material:

1. Looking at the object in use or (if a machine) in motion can reveal information about the tacit shop practices and techniques of the culture that produced it.
2. Performing a technical analysis of a manufactured object can reveal the process of manufacture, through contemporary accounts as well as retrospective accounts by producers and users.
3. Simulating an object can test behavior and evaluate design expertise through models.
4. Testing actual objects through use can reveal norms of precision.
5. Microscopic analysis of surface markings and looking for consistency in dimension and weight may be evidence of skill and motive.

23. Kopytoff, "Cultural Biography of Things," p. 66.

Corn identified each of these methods in specific case studies, mainly of objects from periods where other forms of documentation were not plentiful. Using a case study of a pin-making machine by Steve Lubar to illustrate the first modality, Corn argues that documentary sources (patent records) showed that there were many ways to make a pin machine, but the way the sample was made indicates choices based upon "specific beliefs and practices" because it mimicked manual assembly-line practices.[24] This was only apparent when Lubar experienced the machine functioning, which underscores an argument recently made by Deborah Jean Warner that objects—scientific and technological artifacts and instruments—are interesting because they are functional and therefore should be interpreted in terms of their "performance characteristics." Performance characteristics include all aspects of the building and use of the objects—the skills of design and manufacture involved, the ways to operate them, repair them, and finally, how they are disposed of after their production life.[25]

None of Corn's methodologies apply across the board, and there is significant overlap between some of them. Still and all, it is a useful exercise in articulating how objects have been found to increase historical knowledge and understanding. One finds examples from the history of astronomy that fit one or more of these methods. For instance, there is the famous case of the Antikythera mechanism that significantly improved understanding of the complexity obtained by the Greeks in gearing and clockwork.[26] Modern interferometric studies of optical elements of 17th-century telescope makers like Torricelli, Divini, and Campani revealed the level of their optical polishing technologies and improved understanding of the limits of telescopic knowledge of that time.[27] However, once we get beyond the 17th and into the 18th and 19th centuries, it is typically archival investigation that yields the most telling information about technological capabilities, as in Robert Smith and Richard Baum's excellent study of William Lassell's reflectors, whose optical imperfections led him to believe that he had detected a ring around the planet Neptune even though he was aware of those imperfections.[28] But examples are harder to find when one moves into the contemporary era. This trend is

24. Corn, "Object Lessons/Object Myths?" p. 37.

25. Deborah Jean Warner, "A Matter of Gravity, with reflections on the differences between Gizmos and Works of Art" (unpublished manuscript; text kindly provided by Warner in advance of presentation, March 2005).

26. Derek De Solla Price, *Gears from the Greeks: The Antikythera Mechanism—A Calendar Computer from ca. 80 B.C.* (New York: Science History Publications, 1975).

27. Mara Miniati, Albert Van Helden, Vincenzo Greco, and Giuseppe Molesini, "Seventeenth-century Telescope Optics of Torricelli, Divini, and Campani," *Applied Optics* 41 (February 2002): 644–647.

28. Robert W. Smith and Richard Baum, "William Lassell and the Ring of Neptune: A Case Study in Instrumental Failure," *Journal for the History of Astronomy* 15 (1984): 6–15.

likely similar for all types of collecting. The history of the technical museum in Western culture reflects this trend.

Originally collections of antique instruments, machines, patent models, and industrial products, in the 20th century, technical museums became venues to commemorate "native scientific and technological genius" as well as to supplement the academic program attendant to a technical education: if there was a trend, it was toward commemoration and pedagogy. Thus the technical museum became what Robert Multhauf has described as "a laboratory course extended in space rather than in time, arranged in some historical sequence to exploit the value of historic apparatus." These museums were also initially regarded as repositories of knowledge and inspiration insofar as they acted as places where inventors, designers, and engineers could go to get new ideas or to solve specific problems in design and manufacture. This application, however, closest to Corn's ideal methodologies, proved to be transitory; it was merely a passing interest through the early 20th century. And so the trend moved on once again, when technical museums returned to promote industrial products and act as places for the "preservation of our cultural heritage and to the inspiration of young people with an interest in science and technology."[29] Multhauf's goal in this 1958 essay was to highlight the limitations of perspective: "Unlike the engineer of the last century," he pointed out, "we begin our training, and rest our work, upon a basis of knowledge much of which is outside our own experience."[30] Therefore, for Multhauf, technical museums were the best places where one could explore, through utilizing all available primary and secondary source material, the many ways that discovery and invention happen, the very human artificial element in the inventive process.

Like Kranzberg, Multhauf did not actually regard the thing itself as embodying knowledge, but rather as a locus for the gathering in of knowledge in all forms and with increasing and changing perspective over time. His allusion to how the experience of the engineer of the last century differs from our experience offers testimony to how one needs to read an artifact: a worker who experienced the development of a technology before it was successful and before the principles upon which it was based were fully worked out would see that artifact very differently than someone looking at it years later, after it had proven itself and the principles it embodied. All the doubt, uncertainty, and promise congealed within the artifact can only be assumed, unless one has at hand numerous accounts of attempts made in that day to solve the same functional problem or goal, like attaining the facility of traveling in space and then having to learning how to work in that new theater, or how to build a

29. Robert P. Multhauf, "The Function of the Technical Museum in Engineering Education," *Journal of Engineering Education* 49 (December 1958): 200.

30. Ibid., p. 200.

pin machine that would be acceptable to piece workers, or a rifle that could be assembled, disassembled, and made reliable in the field.

To a certain extent, episodes in the recent history of the National Air and Space Museum's space history collection bear out this transitory phase, but they also show that it lingers even today and no doubt will be present in the future. The NASA/NASM Transfer Agreement explicitly states that if NASA decides that an object it had transferred to the national collection somehow reacquired its usefulness to the space program, it would be recalled. Sometimes this works, sometimes not. When the Viking 1 lander failed to call home from Mars in November 1982, NASA engineers came to the Museum to inspect the computer inside the engineering model we display in the Milestones of Flight gallery, hoping that their inspection might help them figure out how to regain communication with the lander. Unfortunately, the box holding the on-board computer in our example, although real, was empty of its contents. Our *Skylab* orbital workshop, originally built for flight, has been on display since 1976, though modified to allow visitors to walk through the living quarters. In the early 1980s, Marshall Space Flight Center engineers requested the return of a set of circulating air fans and, a few years later, came to inspect the toilet systems, since surviving documentation was apparently unobtainable when they were looking for ways to adapt these designs for new human space initiatives. And on occasion, engineers and scientists have expressed interest in everything from our Saturn F-1 engines to the backup Hubble Space Telescope mirror now on display. In the case of the engines, the engineers sought out the technical documentation we held in our archives rather than the object itself.

Multhauf's views on the use of objects in pedagogy were reflected in at least one of Corn's methodologies, as well as by some of the presentations at a 1975 conference at the Winterthur Museum held to explore how material objects are useful to the study of American history. Historians, archaeologists, ethnologists, American studies specialists, and even a molecular chemist spoke from their perspectives and experiences. James V. Kavanaugh suggested how a course in American studies could be augmented by using anthropological techniques upon "accumulated material evidence" to more fully explore the culture of invention in American life.[31] Cary Carson, Saint Mary's City Commission, echoing Corn's later observations, argued that artifacts have not contributed at all to "developing the main themes of American history" but have, in their design and arrangement, especially in the buildings of surviving early communities, certainly helped to fill in the details and provided new

31. James V. Kavanaugh, "The Artifact in American Culture: The Development of an Undergraduate Program in American Studies," in *Material Culture and the Study of American Life*, ed. Ian M. G. Quimby (New York: W. W. Norton, 1978), pp. 65–74.

insights. Facing the allegation that things "have seldom been a source of ideas for historians," he argued that by looking differently at objects, the mind is certainly capable of thinking up questions that they can answer or contentions they might prove or disprove. Embracing Kranzberg's "New History," Carson argues that "bottom up" history can often best be reconstructed by looking at the details of living environments, and thereby it can pose new questions. The experience of life, of "society as a working organism," can best be appreciated by somehow encountering the material vestiges of that experience. Although he applied his methodology to 17th- and 18th-century life on the Eastern Shore of Maryland, showing how "architecture became the instrument of segregation" and other insights, one might map these concepts into an exploration of the contemporary dwellings of scientific instruments and space operations.[32] Building upon a recent comment by Pam Mack, it is one thing to examine graphic profiles or even photographs of the interior of a Mercury capsule. But it is quite another to actually experience that tiny space, looking from the outside, of course.[33] Possibly someday someone might ask the crowded and complex chamber specific questions relating to the actual role of the astronaut in the Mercury, Gemini, and Apollo eras that cannot be answered as completely or as poignantly by other forms of indirect documentation. One might also find such reminiscences in debriefing documents after the flights. Definitely riding in a machine and being part of its operation is a most valuable experience. Many historians have expressed how important it has been for them to fly in an aircraft they have studied; Ron Davies at NASM recently commented that it was an essential experience, even though his primary data came from airline timetables.[34]

Probably the most eloquent argument for the value of experience at the 1975 Winterthur Conference was Brooke Hindle, who was the lead speaker. Hindle was then Director of the National Museum of American History, and he took the occasion to explore the essence of material culture in his now-classic "How Much Is a Piece of the True Cross Worth?" Hindle identified the factors that led him to what we today might call "priceless." Pondering Lenin's body, Dolley Madison's gown, Ben Franklin's printing press, he first stated that artifacts provide "direct, three-dimensional evidence of individuals who otherwise exist only as abstractions in words, paintings, or monuments."[35] In order to utilize them properly, however, one has to know how

32. Cary Carson, "Doing History with Material Culture," in *Material Culture and the Study of American Life*, ed. Quimby, pp. 42–50.

33. Telephone conversations with Pamela Mack, February 2005.

34. Ron Davies, personal communication in response to informal questionnaire sent to NASM curators, February 2005.

35. Brooke Hindle, "How Much Is a Piece of the True Cross Worth?" in *Material Culture and the Study of American Life*, ed. Quimby, p. 6.

to apply "linguistic models to the nonverbal, three-dimensional world." This, however, was not a simple matter for Hindle, who felt that language "floats on top of the material world" and so remains separate from it. One must walk the battlefields, cruise the oceans, make landfall as explorers did, to find the words appropriate to the experience. Only in this experiential way, Hindle felt, "the abstractions of language are penetrated by direct knowledge of life's complex multidimensional and instantaneous character."[36]

Hindle's concept of the importance of experiential reality underscores what is, in fact, both a compelling but essentially still abstract circumstance. He did not describe any one set of analytical tools one must bring to the experience in order to sense it and then reduce it to language. He provided examples, as all writers of this genre tend to do, and many of those are compelling, such as Eugene Ferguson's attempt to reconstruct the methods of artisans by showing how they thought in pictures, suggesting that one might do the same for the builders of machinery. His strongest suit, of course, is how the techniques of industrial archaeology have radically changed our view of Eli Whitney's role in the development of interchangeable parts. This was indeed a wonderful example of how, in a manner suggested by Carson and others, asking the right questions of a set of artifacts yielded new knowledge about their history and provided a correction to the broader history of industrial technology.

The success of the interchangeability study naturally raises the question of what is important about today's space technology, especially what is important that might be studied by examining artifacts in the ways Corn and others suggest. Is the ability to exchange parts important in the technology of space history, does it define modern capabilities and practice? Does it typify an era? The answer is probably no, at least not in the way rifles illuminated manufacturing techniques of their day. However, a modern counterpart might be the ability to ensure consistency and reliability across a very widely spread-out system or infrastructure. How sure is an instrument developer, for instance, that his instrument will work within the environment of a satellite housing that has been launched into space? What steps does that developer take to design his instrument to be as forgiving and robust as possible—resistive to vast swings of temperature, pressure, and acceleration, yet sensitive enough to get the job done effectively? This is only one of many questions about "integration" that has been an issue ever since scientific instruments were flown on vessels that were not under the direct control of the instrument maker or scientist.[37] The need to integrate a scientific instrument into a system used either remotely or by surrogates changes the way science is done and certainly

36. Ibid., pp. 9–11.

37. David DeVorkin, *Race to the Stratosphere: Manned Scientific Ballooning in America* (New York: Springer-Verlag, 1986).

changes the experience of the scientist, much as the telephone changed how we communicate. A more obvious approach might be to compare designs of instruments flown on different vehicles, looking for changes or shifts that are only understood in terms of the capabilities of the vehicle. These and other questions can be asked by historians of space artifacts, whether they be launch vehicles, manned or unmanned craft, subsystems, or instruments.

Historians of this contemporary scene might be more interested in issues such as how nations achieve new levels of capability or performance (as with Campani's lenses), how design variations reveal compromise, or how adaptations were made to existing technologies to make them work in the space environment or to survive launch or landing. But unlike the study of Campani's lenses, it is doubtful that the space historian will ask these questions of the artifacts themselves.

Indeed, one usually finds questions directed to the nature of the individuals or organizations that produced the technology. Among historians contributing to the *Osiris* volume "Instruments" in the early 1990s, Robert Smith and Joseph Tatarewicz represented space history, showing how the technical complexity of the Hubble Space Telescope not only symbolizes the complexity of the institutions and motivations involved in creating the thing, but also revealing how these motivations were often in conflict. It is clear from their study of how the largely untested charge-coupled device (CCD) became the detector of choice for the critical Wide Field/Planetary Camera that one can only hope to understand the ultimate technological artifact through the interactions of conflicting institutional priorities between science, the military, and NASA, each possessing different goals, different resources, and different agendas.[38]

This study of the CCD and the complexity of HST gets about as close to the artifact as I have seen in the literature of space history. It is typical of a small but hopefully growing literature that uses some characteristic of the hardware to inform a larger story. But the majority of the literature of space history is still rather far from this sort of treatment. Major characteristics include early practitioner histories, going into great detail describing examples of early rocketry and speculative space vehicles but asking few, if any, questions about them that informed broader historical interests. The NASA-sponsored histories of the 1970s, '80s, and '90s focused, correctly, on the elucidation of missions and the application of broad technologies, rarely focusing on specific examples of the technology and questions about their origin and application. Among the synthetic reviews and disciplinary histories, one often finds descriptions of objects, who built them and why, and what they did, but

38. Robert W. Smith and Joseph N. Tatarewicz, "Counting on Invention: Devices and Black Boxes in Very Big Science," *Osiris* 9 (1994): 101–123.

rarely, if ever, is an artifact in a collection at the center of attention or used in any explicit way in the analysis.

One can find this attitude explicitly stated in some of the papers from the XIX Scientific Instrument Symposium in September 2000, held in Wadham College, Oxford, where a session was devoted to "Instruments in the 20th Century," organized by Paolo Brenni. Speakers said the usual things, like how instruments might provide useful information when other documentation is lacking, but gave no hint in their abstracts of the kind of information one might extract from an instrument other than suggesting that one look at an instrument or actually use it in performing an experiment. The most refreshing remarks about the value of collecting were made by Roland Wittje, who pointed out that any collection of 20th-century instrumentation was for purposes of exhibition and not for the study of history.[39] In other venues, historians have said much the same thing. Marvin Bolt of the Adler Planetarium and Astronomical Instrument Collection, echoing a strong and persistent theme among educators, presented demonstrable evidence for how historical replicas can reveal physical and chemical processes more simply than modern devices. Others concentrated on how, reflecting Hindle, an encounter with an historical object can stimulate greater interest in the subject matter surrounding the actions of that device and the efforts of their human creators and users.

We have touched on Hindle's experiential argument before. It continues to appear in a wide range of studies. An excellent example is Paul Forman's recent study of three mechanical wave guides from I. I. Rabi's early research program that were part of the museum's accession of his materials after his death and his office was cleaned out at Columbia. Paul was already interested in Rabi, of course, but, stimulated by the existence of these relics, he realized that their survival after all these years confirmed that Rabi regarded these early experiments very dearly and saved the devices as a result, even though they were completely overshadowed by his later work that won him the Nobel Prize. This encouraged Paul to search out the nature of his early work, and he found it to be more significant than hitherto realized. These wave guides also confirmed designs previously known only from publications.[40]

At the same 1999 Artefact Conference where Paul Forman reported on Rabi's devices, Paul Ceruzzi recalled an incident where someone examining a circuit board recognized that it was probably designed by the legend-

39. Roland Wittje, "How Can Scientific Instruments Teach the Historian about 20th Century Physics?" in *Session VII A: Instruments in the 20th Century*, session abstract, *http://www.sic.iuhps.org/conf2000/ox_s07a.htm* (accessed 18 January 2005).

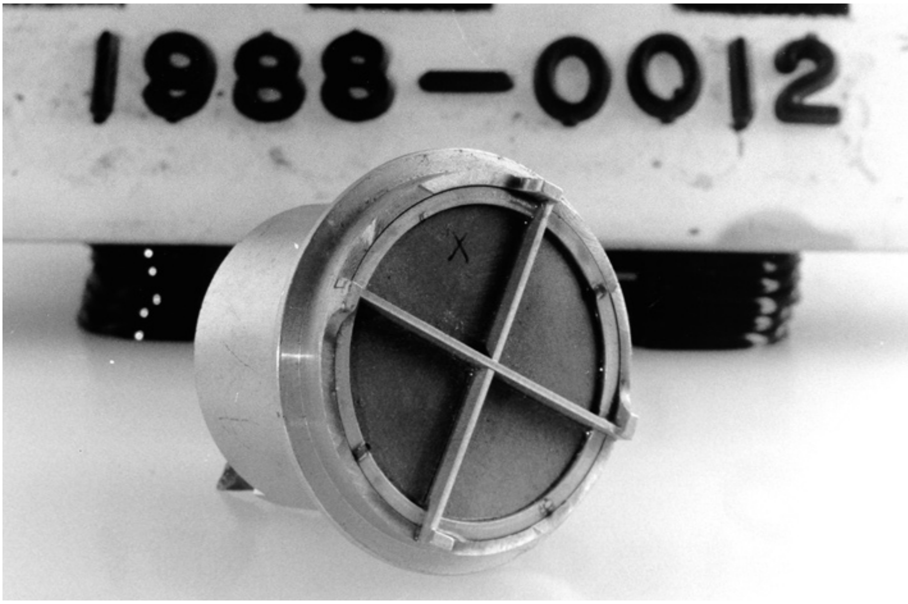
40. Paul Forman, "Researching Rabi's Relics: Using the Electron to Determine Nuclear Moments Before Magnetic Resonance," in *Exposing Electronics*, ed. Bernard Finn, Robert Bud, and Helmuth Trischler (Netherlands: Harwood, 2000), pp. 161–174.

ary Seymour Cray because it had specific design earmarks that Cray had pioneered, specifically his "cordwood packaging" technique that achieved greater densities than hitherto attained. There were no markings on the board other than the known fact that it was part of a military mainframe called the Naval Tactical Data System, or NTDS, built by Sperry. This was a highly specialized machine known only within military circles, and nothing was known about its design. It was also not generally known that Cray worked for Sperry, although he left Sperry before the NTDS was delivered. There is little in the published record linking Cray to the NTDS—no reference in the technical manuals or other contemporary descriptions. In presenting this analysis of a design style and using it to discern design origins in other computing devices, Paul examined a CDC 3800 acquired by the National Air and Space Museum, finding the same packaging design, even though no documentation has yet been found identifying it as a Cray design. Paul describes this as a "reading of the text of the machine itself" and is using it as a guide to search for traditional documentation.[41]

"Reading the text of the machine itself" includes many other areas beyond the survival, existence, or design style of a device, but quite frankly, it is a circumstance that is not as common as one might like. However, there are ways to increase the chances that a reading of an artifact will result in new, useful knowledge. Here I offer two examples from my personal experience: one involves documentation efforts, and the other involves exhibit preparation. Both, by their nature, required the survival, existence, and availability of artifacts.

The first example deals with the use of video to document objects. In the late 1980s, the Smithsonian decided to experiment with the use of video recording to better document its collections. This program, sponsored by the Sloan Foundation, brought together artifacts with their makers and users. As part of this effort, between 1988 and 1990, I interviewed sets of scientists and technicians who had been involved in space research at the Naval Research Laboratory from the 1940s through the 1980s. During the course of these interviews, sessions were devoted to voice-overs of a series of slow pans through laboratories and workspaces, followed by on-camera "enactments" and, following that, by direct examination of artifacts, mainly x-ray and ultraviolet detectors, collimators, and other elements of flight systems. I could fill many pages with examples of how this experience produced evidence that documented the interface between an instrument and its builder, as well as the interaction between the instrument and the laboratory environment within which it was designed and tested in prototype fashion. We documented design

41. Paul Ceruzzi, "The Mind's Eye and the Computers of Seymour Cray," in *Exposing Electronics*, ed. Finn, Bud, and Trischler, pp. 151–160.



Typical x-ray ionization chamber designed, built, and used by the Naval Research Laboratory team on sounding rocket flights in the 1950s and early satellite systems. *(File no. A1988-0012000, NASM Curatorial Files)*

choices, instrumental styles, experimental procedures, and testing methodologies, not merely through reminiscences, but through recording the tactical connection between instrument and builder. On one occasion, one scientist demonstrated the methods used to fill halogen Geiger counters with gas and then test them for sensitivity. He used a contemporary filling station as a backdrop, but his hands twisted invisible dials and stopcocks as if he was using one from the 1950s. They were literally imprinted in his tactile memory. These explorations of working environments gave body to other sessions where the people who built these detectors talked about them while they handled them. Edward T. Byram was faced with many detectors he had built, laid out on a table in front of him. He rarely took his eyes off the detectors during the interview, and when asked if his efforts making these devices work properly were frustrating, he replied: "I was never frustrated. I enjoyed fighting them. It wasn't a frustration, it was a challenge. It was mind over Geiger tube."[42] His behavior matched his rhetoric—throughout the interview, Byram's gaze

42. E. T. Byram, quoted in David H. DeVorkin, "Preserving a Tool-Building Culture: Videohistory and Scientific Rocketry," in *A Practical Introduction to Videohistory*, ed. Terri A. Schorzman (Malabar, FL: Krieger Publishing, 1993), pp. 125–137.

Early halogen counter with an entrance window of mica, capable of sensing ionizing ultraviolet radiation. Note the suspended anode just behind the mica window. This is a tube similar to the one Kreplin tapped during his video-history interviews. *(File no. A1988-0010000, author digital file, NASM Curatorial Files)*

remained on the tubes. Obviously, he was still very attached to them, attached to devising ways to adhere exotic radiation entrance windows onto their shells and ways to ensure that the halogen gas mixtures he was filling them with did not leak or cause the seals to deteriorate. And finally, one of Byram's colleagues, Robert Kreplin, was also asked to talk about the tubes he built. He held an early example while he talked, and in the review, I noticed that as he discussed ways to test the mechanical integrity of these detectors, which had to survive the launch of a rocket, he instinctively tapped the side of the tube and peered through the mica window at a small protruding wire anode. His tapping was reminiscent of the group's concern for the survival of the anode, which in later models was supported at both ends.[43]

Although my basic goal for these interviews was to produce a collective profile of what I deemed to be a tool-building culture at the Naval Research Laboratory and to explore aspects of that culture, I also came away with a better appreciation for how these people organized themselves, raised issues and

43. Image of Kreplin holding a tube, in DeVorkin, "Preserving a Tool-Building Culture," p. 134.

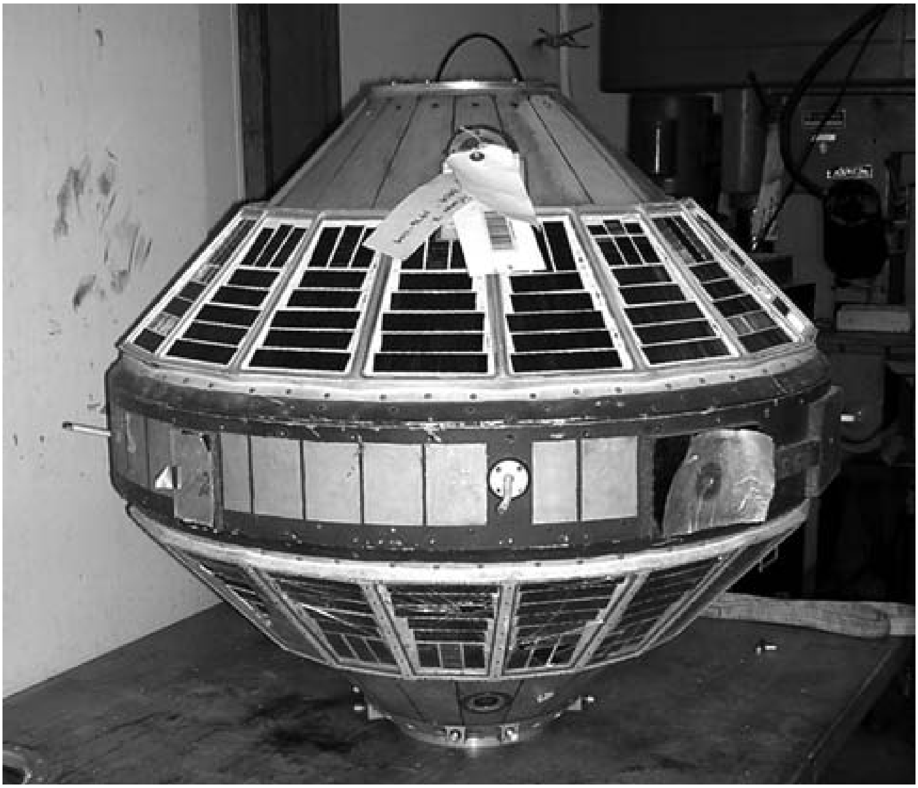
problems, and dealt with outside entities first in the Navy and then at NASA. In a very definite, though not explicit, way, I feel that the surviving artifacts that we interrogated, and which are now in the collection, stimulated memories and physical responses and led to discussions between team members that rekindled behaviors that I could actually discern. From this vicarious experience, I feel I gained a fuller portrait of this tool-building culture.

As my second example of the stimulus generated by a surviving artifact, I turn to recent activities preparing for NASM's new Udvar-Hazy Center. Curators had an unprecedented opportunity to examine a significant portion of the collections in a process that included improving documentation, preservation techniques, and methods of monitoring them, since from now on they will be on permanent display/storage. In the past, various factors have limited our access to these objects. They were stored off-site, sealed and boxed up, and required manpower and coordination for examination. One of the dozens of objects I had never had the chance to fully inspect was a model of the Explorer VII satellite identified as a "full scale replica." It had been acquired on paper in 1976, inventoried several years later, but never actually examined at the Alabama Space and Rocket Center, where it was presumably on display. It finally was shipped to the Garber Facility in 1989. It was quickly inspected, but the box was never actually opened, nor were the insides of the object inspected. As a replica, it was, frankly, not of great interest. As to documentation, we were left with hardly more than a shipping document.

In the years leading up to preparation for the Udvar-Hazy facility, our department's sensitivity for the critical importance of adequate documentation vastly improved. Udvar-Hazy afforded me a chance to acquire intimate knowledge of a set of early satellites and the scientific instruments they hopefully contained, so I opted to examine Explorer VII as part of a suite of first-generation geophysical satellites.

Typically, anything marked as a mock-up or replica or even reconstructed satellite is not going to contain actual flight hardware, so I was really not expecting much. However, many of those objects hauled out and destined for Udvar-Hazy labeled replica or model have turned out to be very real. Based upon my experience with the videotaping of NRL detectors, I quickly realized that the detectors in the skin of Explorer VII were, in fact, real. One detector had a clear entrance window revealing a small chamber that had a single wire on the cylindrical axis, just like the one Kreplin was tapping. Explorer VII may well have been a flight backup, which means that everything about it is real. Documents in our technical files in the NASM library confirmed that the detectors were indeed built by the NRL group, and other elements of the craft closely matched the descriptions in an extensive Technical Note.

None of this effort would ever have been made if I had not been compelled to answer detailed questions raised by an intimate inspection of an



Explorer VII before cleaning and evaluation. Note that the artifact inventory tags were tied to a damaged x-ray detector similar to those examined at the Naval Research Laboratory and recorded during video-history sessions. See the image on page 593 for an intact example. *(File no. A1978-1109000, author digital file, NASM Curatorial Files)*

artifact. Explorer VII is interesting as a representative of the state of technology available for multifaceted studies of solar radiation and the nature of the low-Earth-orbit environment in the late 1950s. As with any early flight, there were some technical "firsts" and at least one first for science: the detection of micrometeorite impacts. But whether or not the remnants of the craft itself reveal anything beyond what is still available from our technical files, at NASA, in our archives and oral histories (with people like Herbert Friedman and James Van Allen, another instrument principal investigator on Explorer VII), or from the published literature, it remains a fact that in the process of inspection and evaluation, more documentation was gathered and consistently filed away than was available before, and hence is likely to be retrievable in the future. Scattered documentation was collected, recorded, and filed away, hopefully someday to be of use in some unpredictable way, stimulated by motivations that we cannot predict. My contention is that the motivation would come either from the recognition someday that this was a watershed flight in space history (the first application of passive techniques of thermal stabilization) or that an artifact that has survived in a major collection calls out, by its very existence, for attention to the fine structure of nuts-and-bolts history, for only through such efforts is a full picture of the nature of the first years of true space research likely to emerge.

So, Why Collect?

As I prepared my remarks for the "Critical Issues" conference, I queried colleagues at NASM, asking them questions stimulated in part by Corn's findings but also by my inability thus far to find unequivocal evidence of how an object relating to space history has actually been used as a source of historical knowledge. I also queried aeronautics curators as a cursory check on a collecting area where documentation tends to be not as rich or institutionally based. In general, the responses confirmed the impressions I was getting from the literature and from experience. Curators (John Anderson, Michael Neufeld, Ron Davies, Tom Crouch, and Jeremy Kinney) typically felt that direct and personal experience with an artifact stimulated them to make historical inquiries. Neufeld, in particular, felt that an encounter with an historical object can stimulate intellectual interests and makes the past seem more real, less dry and distant even for academic historians, but how much they drive any historiography is questionable. Others, like Tom Crouch, felt that they learned from these inspections and gained important intellectual insights. For Crouch, "interpretation . . . was in large measure based on a combination of examining the objects and knowing the documentary record." Jeremy Kinney reported that what he learned from his detailed inspection of variable pitch propellers in the collection is reflected in his publications in significant ways, but that his physical inspections largely confirmed textual descriptions in primary sources. All felt more or less strongly that the survival of artifacts could be a stimulus to researching and writing history. Artifacts provide information on design and shop practices that run hand in hand with the intellectual methods of aeronautical engineering. As for the limits on collecting and the importance of the survival of the "real thing," Tom Crouch added that it is impossible to preserve all the details of a machine (the written and visual records are approximations); close examination always reveals more detail—small mechanical details. For Crouch, one of the museum's failings is the lack of attention to machine tools and production machinery—transitions from one medium (wood) to another (metal) and from metal to modern composite materials are always constrained by fundamental changes in tooling and production machinery. Reflecting issues raised by Warner and others, he also sees a problem with collecting "black boxes" if it is not possible to "turn them on" and examine their behavior. Finally, reflecting Jim Bennett's qualification cited under the title to this essay, he suggests that we all have to consider carefully what we collect for exhibit and what we collect for research—these are not necessarily the same class of object, and selection rules may tend to be very different.[44]

From the arguments so far reviewed from the literature, from the responses of my Museum colleagues here, and from my own experiences, what conclusions do I draw as to the value of collection and preservation? Here is a brief summary of my impressions. Objects can provide the following:

1. Validation—material proof that something happened in space history (Hindle). This requires solid information on provenance, however, and requires as well that the object that is experienced by the visitor was actually the very same one involved in the historical episode it preserves. Collections in space history are rather peculiar in that, as often is the case, the actual historical object that performed the act or the function deemed worthy of note is not accessible—it has been used up or lost in the process of conducting its business, or, simply put, it is still "up there" where we put it, and we have no known means or the wherewithal of retrieving it. There are very notable exceptions, of course: vehicles that have returned to Earth as part of their mission or, even rarer, have been returned to Earth through some conscious act unrelated to the historical event or process that made it noteworthy. For all the rest, we are left with some form of surrogate: an exact flight backup, just like the flight model in every way except that it, in and of itself, did not experience the final act of making history but was still very much a part of that history. It had a role in that process but definitely comes in second place. Third place are various levels of engineering models and mock-ups, reconstructed replicas using parts that were fabricated out of the same computer program, melt, or block. And a distant fourth is all sorts of replicas or reproductions. Are these approximations merely surrogates for the "True Cross," or does each and every one of them tell a particular story that is available no where else in quite the same way? What does their existence, and their survival today, reveal about the culture in which they were made?

2. Celebration—sense of transcendence promoted by physically encountering an object that made history. Accompanies commemorative

44. Responses to curatorial questionnaire, author files, copy available in chronological publication files, NASA Historical Reference Collection, Washington, DC.

or memorializing events, lends visibility and weight to these efforts (NASM legislation).

3. Inspiration—evidence of challenges met or exceeded, handicaps overcome, struggles vindicated. Promotes insight into ways to illustrate basic principles of science and technology (Multhauf, Corn, Bolt).

4. Illumination—preserves something about an historical event, era, or trend that, when means of interpretation are devised, provides additional knowledge that otherwise would not be available. Objects can survive for specific reasons, and searching out those reasons illuminates history (Corn, Lubar, Ceruzzi, Forman).

5. Stimulation—the preservation of an object stimulates interest in it and efforts to learn about it and the history it symbolizes or represents. It also obligates those responsible for its curation to ensure that adequate documentation is collected and preserved to understand it in the future (Explorer VII, Forman, curatorial questionnaire).

Of course, neither celebration nor inspiration actually requires the survival of an artifact, though it would clearly help. Even illumination and stimulation are possible without the real thing, though impact would be even more restrictive. Nothing but the actual object, however, can provide validation—no facsimile, replica, reproduction, or description will ever suffice, although the survival of any of these items still stands testimony at some level.

Afterword

If the survival of an artifact is useful to history in any of the five categories listed above, one still has to look beyond history to the institutions that house and somehow represent it to ask how they react to the suggestion that collections are important to their own survival. In a recent Smithsonian survey cited as significant by the *Washington Post*, 60 percent of the respondents claimed that they were visiting the Mall museums to see "the real thing," whether it is Dorothy's red shoes or the Apollo 11 capsule.[45] The *Post* itself was concerned with what motivates programming at the Smithsonian in its efforts to overcome the tourist slump after 11 September 2001. Ironically, the part of

45. "Smithsonian Institution Office of Planning and Analysis Report" (internal document, 2004), quoted in J. Trescott, "The Smithsonian's Concession to the Bottom Line," *Washington Post* (13 April 2005): A1, A8.

the Smithsonian being covered by the *Post* reporter and as reported by her, its Business Ventures arm, responded as if this fact gave it a "mandate" to push IMAX films, simulators, jazz concerts, and anything else it could imagine would raise revenues. The irony was, unfortunately, lost on the *Post* reporter. Yet the fact remains, the public, when asked in this instance, reified "the real thing" just as Hindle argued it should. This runs counter to opinions voiced by museum watchers and critics in studies over the past several years, who have claimed that, in the face of theme parks and Disneylands, public tastes have shifted "to immersion in an environment, to an appeal to all the senses, to action and interactivity, to excitement, and beyond that to aliveness." And in response to this shift, many modern museums have "shifted their allegiance from real objects to real experience."[46] Oddly, these are just the sorts of experiences that, at least in the case of Smithsonian Business Ventures, a museum can charge money for. No one knows if it is a viable strategy for long-term survival of these institutions as collecting agencies.

46. Randolph Starn, "A Historian's Brief Guide to New Museum Studies," *American Historical Review* (February 2005): 92 (citing statements by David Lowenthal and Hilde S. Hein).