CHAPTER 15

THE HISTORY AND HISTORIOGRAPHY OF NATIONAL SECURITY SPACE[1]

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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

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

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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]

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

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]

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]

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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

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.

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-

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*

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).

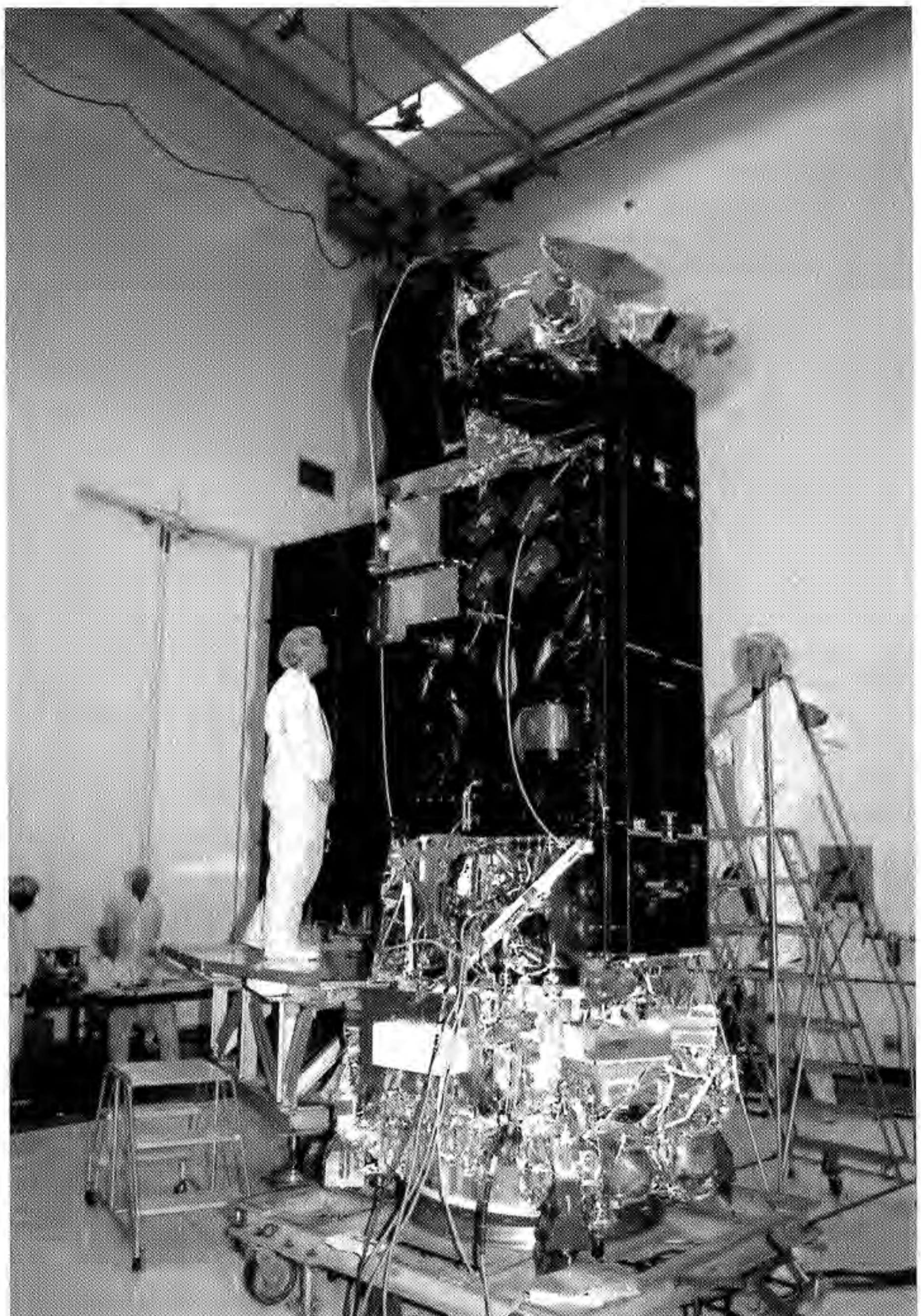
259. Siddiqi, *Challenge to Apollo.*

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

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

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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-

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]

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.