Section III

NASA and External Relations

INTRODUCTION

In achieving its mission over the last 50 years and in pursuit of a variety of goals, NASA has had complex interactions with a large number of external groups. This section discusses three of the most important: the aerospace industry, the Department of Defense, and the international space community. With a few notable exceptions, historians have often submerged these relationships as they concentrated on the internal problems, achievements, and themes of the Agency itself. NASA's relations with any one of these entities would be an enormous topic in its own right; each author in this section has adopted particular case studies that illuminate key issues.

In the first paper, Philip Scranton aims to enhance our understanding of the often contentious interaction between NASA and industry, which has been crucial in designing, testing, and building the hardware necessary to achieve the Agency's mission.[1] This essay gives a vivid accounting of the complexity of the space enterprise at a level that few people outside the space community contemplate. This complexity involves not only the operational relationships between NASA and its prime contractors, but also those among the primes and their thousands of subcontractors, among the subcontractors and the "sub-subs," and so on down the line, all part of the aerospace industry at increasingly diffuse, but real, levels. Scranton points out that while there was (and is) much contention among those in the contracting community, historically all stood together against what they perceived as excessive NASA meddling and oversight. Yet somehow, it all worked (usually) in the end. Drawing on his own work on the fabrication of the Mercury spacecraft; on Bart Hacker and James Grimwood's history of the Gemini program, *On the Shoulders of Titans*;[2] and on Joan Bromberg's *NASA and the Space Industry*, Scranton shows the astonishing array of questions that arise when one considers concrete historical cases.

Beyond his analysis of the problems, Scranton suggests five frameworks for research that might increase our understanding of the relations between NASA and industry, technology and organization, practice and process, and design and production. Two existing frameworks are Stephen Johnson's study of the systems management approach in *The Secret of Apollo* and Howard McCurdy's sociological approach to organizational culture exemplified in *Inside NASA*.[3] Scranton also

1. NASA has sponsored one study of the Agency's relationship with the aerospace industry, but there is considerably more work to be done on the subject. See Joan L. Bromberg, *NASA and the Space Industry* (Baltimore, MD: Johns Hopkins, 1999).

2. Barton C. Hacker and James M. Grimwood, *On the Shoulders of Titans: A History of Project Gemini* (1977; reprint, Washington, DC: NASA SP-4203, 2002).

3. See Howard E. McCurdy, *Inside NASA: High Technology and Organizational Change in the U.S. Space Program* (Baltimore, MD: Johns Hopkins, 1993); Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore, MD: Johns Hopkins, 2002).

proposes that analytical tools be used from the fields of social construction of technology, management theory, and anthropology to attack these problems.

Scranton hopes for a shift in the writing of NASA history in what he sees as a long-overdue direction: the little-understood world of production for NASA. "Retelling NASA stories from the drafting room and shop floor outwards, from the bottom up," he concludes, "has the potential to reorient a universe of NASA-centric histories." He formulates a large number of questions that constitute a research program to this end.

Scranton's essay does not address the Department of Defense, but since the 1980s, DOD has funneled even more money into the space industry than NASA (their respective space budgets were on the order of $19 billion versus $14 billion in 2003). Even before NASA was formed in 1958, DOD, with its growing stock of ballistic missiles, realized the importance of space for military reconnaissance. In the interservice competition to create a scientific satellite for the International Geophysical Year (IGY, 1957–58), the Navy's Vanguard program was given the go-ahead, but it was the Army, with a modified Jupiter C ballistic missile, that launched Explorer 1 on 31 January 1958, the first successful American satellite in the wake of Sputnik. The opening of the Space Age was accompanied by intense discussion as to whether the nation's space program should be military or civilian. NASA's birth signaled the decision for a civilian agency, but the proper role for military and civilian space programs has been debated ever since.

Peter Hays, a policy analyst with 25 years of service in the Air Force, focuses on three key issues and time periods to illuminate NASA-DOD relations. In the first issue, organizing to implement the American space vision in the 1950s, he finds three major activities with bureaucratic interests that endure today: moving the Army Ballistic Missile Agency (ABMA) into NASA, consolidating DOD space activities under the Air Force, and establishing the National Reconnaissance Office (NRO). Once the ABMA was transferred to Marshall Space Flight Center in Huntsville, Alabama, in September 1960, after a protracted struggle, the Army was officially out of the space business; DOD space activities were concentrated in the Air Force. Not trusting reconnaissance satellites to the Air Force, however, President Eisenhower formed what is now known as the NRO in late 1960. DOD and NRO activities became increasingly classified under President Kennedy, a situation that led to widely divergent public and congressional perceptions of the NASA and military space programs and also made the writing of military space history dependent on declassification.

Hays's second issue is the rationale for human spaceflight in the early space program, in particular the competition between NASA and the Air Force for human spaceflight missions. In this competition, NASA was decidedly the winner; the Air Force was rebuffed on its Dyna-Soar effort by the end of 1963 and its Manned Orbiting Laboratory by 1969 (after $1.4 billion in expenditures).

These early interactions among NASA, DOD, and NRO provide deep background for Hays's third issue, the development of the Space Shuttle, which provided "the most focused, longest running, and most intense interplay among these organizations . . . the single most important factor in shaping their interrelationships." As Hays shows and others have suggested before him, in selling the Shuttle project to Congress and the President, and especially once the decision was made that the Shuttle was to be the nation's primary launch vehicle, NASA needed DOD support and DOD needed NASA to launch its large spy satellites.[4] The Air Force component of DOD was essential in determining Shuttle payload and performance criteria and is credited with saving the program during the Carter administration when Vice President Mondale and the Office of Management and Budget tried to cut it. It was the Air Force that successfully argued that four Shuttles were needed. The price exacted from NASA was mission priority for DOD. Yet, because it did not control the Space Shuttle program, the Air Force was never very enthusiastic about it. And in the aftermath of *Challenger*, the Space Transportation Policy underwent a seismic shift, with the Air Force and NRO once again returning largely to expendable launch vehicles. For historians and policy analysts, the Space Shuttle program provides an unparalleled window on the relations among NASA, DOD, and NRO. Hays concludes that it is "an excellent illustration of the general Air Force ambivalence over the military potential of space and military man-in-space as well as evidence of the lack of clear and accepted doctrinal guidance on these issues."

In the third chapter in this section, John Krige asks an intriguing question: why does the most powerful nation on Earth for the last 50 years want or need international space cooperation? As he points out, some have argued that space cooperation was used in the Cold War era and should continue to be used now, under changed circumstances, as an instrument of foreign policy in which to foster and gain allies. But, he notes, blind international cooperation exacts a price: there is a tension among sharing technology, not compromising national security, and remaining industrially competitive. He argues that sharing technology in the interests of international cooperation makes no sense, historically or practically, unless one opens the "black box" of the interaction of technology and foreign policy: "It is crucial to focus on what specific technologies might be available for sharing in the pursuit of specific foreign policy objectives, rather than—as so often happens—to simply lump technology and foreign policy into an undifferentiated whole." Historians must study international collaboration at this fine-grained level, he insists, if the analysis is to be robust.

4. See Dwayne A. Day, "Invitation to Struggle: The History of Civil-Military Relations in Space," in John M. Logsdon, gen. ed., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, vol. 2, *External Relationships* (Washington, DC: NASA SP-4407, 1996), esp. pp. 263–270.

In his essay, Krige takes his own advice by analyzing a particular case of attempted technology transfer: the mid-1960s desire by the Johnson administration to collaborate with Western Europe, particularly with the European Launcher Development Organisation (ELDO), on a civilian satellite launcher. This desire was based on the belief that such cooperation would strengthen European unity, close the technology gap between the United States and Europe, and divert ELDO resources from the technology of nuclear weapons delivery by using them in space instead. NASA and the State Department particularly argued the last point: that by sharing launch technology with ELDO, including documentation on the Atlas-Centaur upper stage that would allow European satellites to reach geosynchronous orbit, they would discourage other nations from applying resources to national military programs. In opposition to this desire for cooperation were American national security and business interests. In particular, some felt that American technology transfer might actually benefit the French nuclear weapons program in terms of its delivery system. Others pointed out that the technology transfer might confer commercial advantage to certain countries in terms of competition with INTELSAT, the worldwide communications satellite consortium under U.S. control via COMSAT. Although NASA and the State Department argued for a finer analysis and a case-by-case study rather than the blunt instrument of national security memoranda, in the end, the argument for relaxing constraints on technology transfer lost. Krige explains the reasons, which are deeply rooted in historical events.

Krige suggests that historically, the protection of national security and national industry interests always prevails over foreign policy considerations. His insights into the connections between space and foreign policy open up a new direction in space history and the history of this component of foreign policy.

By no means do the aerospace industry, the Department of Defense, and international relations exhaust even the general categories of NASA's external activities. Other interagency activities, such as interactions with the State Department and the National Oceanic and Atmospheric Administration (NOAA); university relations, as championed by former NASA Administrator James Webb and some of his successors; public and community relations, always important to NASA's image; and congressional relations, so essential to funding, raise their own unique questions as subjects of historical analysis. Nevertheless, taken together, this section highlights how multifaceted NASA history is, as well as how very much remains to be done in a large number of areas and from a variety of new perspectives.

Chapter 6

NASA and the Aerospace Industry: Critical Issues and Research Prospects

Philip Scranton

The X-15 was [Harrison] Storms' airplane as much as it was anybody else's airplane. A lot of other people could lay claim to it. The theorists at NACA [National Advisory Committee for Aeronautics] had actually laid out the basic lines and drawn up the specifications. Some of these people thought of [North American's] Storms and his ilk as "tin benders," lowly contractors who simply hammered out the hardware to match the vision of the scientists. But this wasn't hardware. This was jewelry.

—Mike Gray, *Angle of Attack*

As costs rose, schedules slipped. One source of delay was attempted improvements . . . . The Gemini Program Office was less than happy with the course of events . . . . Not only was GPO being bypassed in the process that approved changes Lockheed wanted to make, but the project office was not always even told what those changes were.

—Bart Hacker and James Grimwood, *On the Shoulders of Titans*

[Reassignment to] Spacecraft Assembly and Test brought me totally down to reality—down and dirty with the thousands of physical details that had to be perfectly crafted, installed, verified, and documented, and face to face with the earnest, hard-working men and women who strove to do their very best to build a spacecraft that would land men on the Moon and bring them back safely . . . . I had seen the effort and concentration by hundreds of skilled craftsmen that was needed to make engineering orders or program decisions take shape in fact, not just on paper.

—Thomas J. Kelly, *Moon Lander*

In concluding his 1999 essay review of recent works in NASA history, Northeastern University's W. D. Kay noted that however thorough these studies, they "wind up saying very little about the behavior of the private contractors who actually built the rockets, probes, and satellites. With rare exceptions that almost always involve catastrophes . . . the internal workings of the nation's aerospace contractors never receive anywhere near the level of scrutiny routinely accorded to NASA." Tipping his hat to Roger Bilstein's *Stages to Saturn* as a "happy exception" to this pattern, he added his concern that silences on the industrial front obstructed assessment of credit, blame, and "accountability." In this regard, Kay hoped that aerospace companies would disclose the sources that would document their "role(s) in shaping the U.S. space program,"[1] but at least for Mercury, Gemini, and Apollo, mountains of industry documents have been preserved in NASA files and NARA archives, awaiting our attention. Perhaps this essay will encourage scholars to plunge into them bearing questions and agendas that will enrich our appreciation for the business of building space technologies.

During its first years, NASA reluctantly discarded the NACA's "we build it here" philosophy, abandoning its predecessor's approach for an emphasis on design and supervision, project management, and performance review.[2] Rapidly, then durably, the Agency paid out 90 percent of its budget allocations to contractors, chiefly private-sector firms, for engineering, fabrication, testing, redesign, certification, and shipment.[3] These industrial enterprises and their hundreds, perhaps thousands, of subcontractors, constituted the aerospace industry, which commenced in the 1950s chiefly as a series of projects, then divisions, within well-known aircraft companies: North American, Martin, Lockheed, Boeing, Douglas, and McDonnell, supplemented by specialists in electrical or chemical technologies and products (GE, Thiokol).[4] Given the NASA History Office's charge to research Agency plans, programs, and performance, it is understand-

1. W. D. Kay, "NASA and Space History," *Technology and Culture* 40 (1999): 120–127. A number of titles partly addressing Kay's concerns appeared later than his January 1999 publication; some of them will be discussed below.

2. George Mueller, NASA's Apollo director, indicated that in the 1950s, NACA depended on the Air Force to do fabrication contracting for them, thus beginning the shift to externalization (NASM Oral History Project, Mueller Interview No. 4, 15 February 1988, p. 13, available at *http://www.nasm.si.edu/research/dsh/TRANSCPT/MUELLER4.HTM*).

3. Howard McCurdy, *Inside NASA: High Technology and Organizational Change in the U.S. Space Program* (Baltimore: Johns Hopkins, 1993), p. 39. Some of this was interagency transfer, I presume, as ABMA built some launch vehicles and assembled others, but the bulk of it was funding to private enterprises.

4. Over time, the number of prime contractors shrank decisively through a series of mergers and acquisitions, notably the creation of McDonnell Douglas (1967) and its amalgamation with North American Rockwell's Aerospace Division in a Boeing-led merger during the 1990s. Martin acquired American Marietta in the 1960s, then merged a generation later with Lockheed, yielding Lockheed Martin in 1994. The rising cost of aerospace projects (and of military aircraft development) and the uncertainty of profitability made failure on a multimillion-dollar bid extremely painful and made

continued on the next page

able that histories to date have fostered far greater appreciation for NASA's managerial, political, and mission-related achievements and conflicts than for its contractors' struggles to fabricate and qualify spaceflight technologies. Hence the epigraphs aim to evoke multiple dimensions of manufacturing for NASA—the tensions between Agency managers/designers and onsite corporate program directors; the extravagant demands spaceware placed on engineering and production capabilities ("jewelry"); the perennial need for improvements and fixes; that work's impact on costs, schedules, and communication; and the substantive gap between management/engineering plans and the grinding detail work on shop floors and in clean rooms across America.[5]

To rephrase this somewhat, an enhanced understanding of industrial practice in relation to NASA projects could benefit from sustained attention to four core but interrelated themes: 1) initial designing and building of technological artifacts; 2) testing, redesigning, and reworking/refabricating such artifacts; 3) alliances among and contests between contractors, as well as contractors' collaboration with or challenges to NASA units; and 4) approaches to conceptualizing complex contracting and managerial relationships in the production of "edge" technologies. Exploring these will help expose their layers and nested problem sets as this discussion moves toward sketching examples which illuminate recurrent situations, some elements of change over time, and key persistent features of the environment for fabricating aerospace innovations. In addition, this essay will briefly review aspects of the literature concerning aerospace production for NASA, will mention preliminary findings from my work with Mercury spacecraft fabrication records, and will close by offering a set of potential research questions in this area.

NASA AND INDUSTRY: FOUR CORE ISSUES

1) Initially designing and building aerospace artifacts.

The iconic NASA artifacts were launch vehicles and their payloads (manned capsules, satellites, observatories, etc.), yet a significant class of artifacts never experienced the rigors of the extraterrestrial environment (launch apparatus, testing and simulation devices, ground support and tracking/communications equipment, and much more). While being integral to NASA's ability to reach

---

continued from the previous page

consolidations gradually more attractive. See Joan Bromberg, *NASA and the Space Industry* (Baltimore: Johns Hopkins, 1999), pp. 12–13.

5. The epigraphs reference what Howard McCurdy terms the "first generation" of NASA, the era through 1970. That's the only era about which I can profess anything like detailed knowledge, principally as a result of serving as the Lindbergh Chair at NASM (2003–04) and doing archival research at NARA's Fort Worth branch and at NASA Headquarters on the design and fabrication of the Mercury spacecraft.

space and, not infrequently, reusable,[6] they stood earthbound. Ground equipment, whatever its complexity, arguably faced fewer "unknowns" than that which was launched, suggesting two distinct lines of design and production dynamics. Moreover, as will be indicated below, some aerospace technologies were "merely" complex, whereas others severely "stretched" technological capabilities, another line of differentiation which could profitably be cross-compared with the launched and the grounded artifacts' development.

Nonetheless, virtually all these technological artifacts were custom-designed and purpose-built, although NASA leaders at times urged contractors to use "off-the-shelf" components or items proven in use during earlier projects. The design process was intricate and NASA-led in the early years, at times contentious, and staggeringly demanding in engineering effort and precision. Building was likewise intricate but was contractor-led (with the exception of the Army Ballistic Missile Agency rockets and a few others) and NASA-supervised/-critiqued, while being staggeringly complex in project management, quality control, and shop-floor detail—and yes, often contentious as well.

Moreover, beneath the level of large-object systems (rockets, capsules, launch sites, etc.), complexities in design and building animated the production of components, the parts for components, and the spatial/operational strategies for assembly and integration of components into functional systems (electrical power, fuel delivery, instrumentation) before the further integration of those systems into the large objects. Occasions for error abounded, as all historians of NASA know well, and the challenges of detecting errors' causes varied dramatically—from simply identifying a faulty fuse to reassembling the shattered parts of an exploded Redstone.

The engineering implications of failures were plain: "whenever something broke, we redesigned it."[7] The managerial implications were more ambiguous, for NASA officials, contractors' personnel, subcontractors, veteran Air Force project managers (much involved in NASA efforts), as well as for advocates and critics of the space program, in and out of government. Parts, component, and large-object failures were expected, yet they could (and did) derange budgets, stall schedules, initiate blame games, and hazard careers. Tom Kelly's transfer to Spacecraft Assembly, noted in the third epigraph, was a stark demotion triggered by a dismaying array of leaks in the first Moon lander Grumman had proudly delivered to Cape Kennedy, a shock that led him to a fresh learning curve[8] and leads us to theme two.

---

6. Unlike everything launched before the Shuttle era. On the Shuttle as the first reusable space vehicle, see Diane Vaughan, "The Role of the Organization in the Production of Techno-Scientific Knowledge," *Social Studies of Science* 29 (1999): 919.

7. *Inside NASA*, p. 32.

8. Thomas J. Kelly, *Moon Lander: How We Developed the Apollo Lunar Module* (Washington, DC: Smithsonian, 2001), pp. 165–171. This demoralization is noted by Stephen Johnson in *The Secret of Apollo* (Baltimore: Johns Hopkins, 2002), pp. 145–146.

2) Redesigning, testing, and reworking aerospace artifacts.

In aerospace design and fabrication, three "rules" might be regarded as near universals: a) "the distance between paper and product is greater than you think," b) "nobody gets it right the first time," and c) "learn that failure is your friend." These are applicable in part because space manufacturing has to meet more demanding environmental tests than any other category of production.[9] Zero gravity, temperatures verging on absolute zero, the vacuum of space, launch vibrations and postlaunch rocket oscillations (pogo-ing), combustion instability, the complex interdependencies of functional systems, and the impossibility of most in-mission fixes combined with other hazards to render manufacturing for NASA launches a high-risk, high-stress task. Testing, particularly of components and subsystems, routinely revealed shortcomings in materials, workmanship, capability, or durability, mandating redesign, indeed often multiple redesigns.[10] "Fixes" themselves could create new problems—e.g., a redesigned part impinging more on a nearby component than the prior version, now radiating vibrations that unsettle its neighbors' instrumentation. Recognized insufficiencies in a system could trigger a higher-order redesign (classically, realization that fuel cell reliability was uncertain, yielding a shift to batteries),[11] which then entailed rethinking system integration. Occasionally, interprogram redesigns affected the large objects, which tended to present a stable exterior appearance. For example, the Mercury capsule's system components were largely located in the interior space of the "tin can," crowding one another and the astronaut. They were maddening to adjust or repair (getting at a failed part in one system usually involved removing elements of another, adding possibilities for error and failure). However, in the larger Gemini capsules, designers modularized functional systems (all key parts located together, insofar as was possible) and removed them outside the astronauts' operating space, making them accessible from the exterior of the capsule for maintenance.[12]

9. The "rules" are of my devising, derived from (not quoted from) primary sources. Likewise, the "more demanding" claim is arguable, though not pursued here. Comparable, but somewhat less demanding, environments for production, in my view, involve nanotechnologies, biotechnologies, deep underwater artifacts (nuclear submarines), and cryogenic or Arctic/Antarctic processes/places. At the press conference observing the Mercury Project's closure, McDonnell's Walter Burke asserted: "The problem of designing and making work this complex group of systems is one which [required] and did get a degree of attention to detail far surpassing [any] that has ever been evident in any industrial effort up to date." A newsman thoughtfully countered that Admiral Rickover might challenge that claim (transcript, Mercury Project Summary Conference, box 1, "Mercury Final Conference," September–October 1963, entry 196—Subject Files, NASA, Johnson Space Center Files, NARA RG255).

10. As Mission Control's Gene Kranz summarized, "If you were successful, the concept was labeled brilliant, and you could focus your energies on the next step, the next set of unknowns. If you had problems, you found them early and somehow made time to fix them while keeping on schedule. If you failed, a lot of expensive hardware was reduced to junk and the schedule shattered" (Gene Kranz, *Failure Is Not an Option*, New York: Simon & Schuster, 2000, p. 210).

11. Kelly, *Moon Lander*, pp. 83–84.

12. Barton Hacker and James Grimwood, *On the Shoulders of Titans: A History of Project Gemini* (Washington, DC: NASA SP-4203, 1977), pp. 33–34.

In this context, experienced contractors understood that NASA's or their own engineers' blueprint designs represented a preliminary set of parameters for manufacturing, given the multiple uncertainties of testing and use and the unknown unknowns (unk-unks) that could wreak havoc at any point.[13] Thousands of engineering design changes would flow through every large-object project, ripping holes in budgets, but ironically reinforcing the confidence of NASA staff and contractors' engineering and production teams. "As a part of their culture, NASA employees came to believe that risk and failure were normal" and that the anticipation of failure led to its avoidance.[14] Hence the salience of acknowledging the long road from sketch to artifact, the necessity of iterative design and testing, and the value of welcoming failures (though obviously not fatalities).

3) Contests and alliances between/among contractors and NASA units.

One could hardly do better for a starting point in thinking about managerial relationships in high-performance technological production and operation than to revisit W. R. Scott's classic formulation of three central issues:

> We expect *technical complexity* to be associated with structural complexity or performer complexity (professionalization); *technical uncertainty* with lower formalization and decentralization of decision making; and *interdependence* with higher levels of coordination. Complexity, uncertainty, and interdependence are alike in at least one respect: each increases the amount of information that must be processed during the course of a task performance. Thus as complexity, uncertainty, and interdependence increase, structural modifications need to be made that will either 1) reduce the need for information processing, for example by lowering the level of interdependence or lowering performance standards; or 2) increase the capacity of information processing systems, by

13. A concise evocation of the "unk-unks" (famously referenced in a 12 February 2002 press conference by Defense Secretary Donald Rumsfeld) can be found in Tom Kelly's analysis of the Apollo Lunar Excursion Module's (LEM) history. Having completed a preliminary design study for Grumman, Kelly's partner Tom Sanial opined: "'I'll bet the real Apollo won't look like any of the vehicles we've studied.'...'Why do you say that? Don't you think we've done a good job,' I challenged. [Sanial replied,] 'Our study was okay as far as it went, but I'm sure we've just probed the obvious. There's still so much we don't know about how to fly to the Moon.' I had to agree with that. 'You're right. We don't even know yet what we don't know'" (Kelly, *Moon Lander*, p. 16).

14. McCurdy, *Inside NASA*, pp. 62–65. For me, at least, it is not clear, in practice, with what reliability anticipation of failure does lead to its avoidance, or indeed how one would know/measure/analyze this. This may be one of those rarely voiced articles of faith that I have elsewhere referred to as "fabrications." See Philip Scranton, "Cold War Technological Complexities: Building American Jet Engines, 1942–60" (unpublished paper presented at SHOT Annual Meeting, Amsterdam, October 2004).

> increasing the [flow and carrying] capacity of the hierarchy or by legitimating lateral connection among participants.[15]

Todd La Porte and Paula Consolini appropriated this conceptualizing statement as foundational for their studies of "high-reliability organizations," working a counterpoint to the normalization of complex technology/system failures evident in Charles Perrow's analyses.[16] Having done workplace studies, they argued that with enough attention to detail, procedure, and training, complex organizations can and do manage to handle high-risk situations without catastrophic consequences. Yet the situations their air traffic controllers and aircraft carrier landing technicians mastered were characterized by long-term stable technologies, high-volume repetitions, and thus a restricted, known set of risk-enhancing conditions and emergency-inducing variables (chiefly technical failures and cascading climate problems). Though they partook of Scott's three core features, NASA production and operations did not fit this high-reliability stabilization framework, for these were nearly unique phenomena, lacked technological stability, lacked mastery-inducing repetitions, and thus confronted hazard conditions and variables that could not be fully comprehended, much less defended against by backups and redundancies.[17]

One implication of this difference was that for technological, economic, organizational, and cultural reasons, contracts proved blunt instruments for regulating the production and operational relationships between NASA and its contractors, much less among NASA and primes on one hand and thousands of subcontractors (and sub-subs) on another.[18] Technically, the

---

15. W. R. Scott, *Organizations: Rational, Natural, and Open Systems*, 2nd ed. (Englewood Cliffs, NJ: Prentice Hall, 1987), quoted in Todd La Porte and Paula Consolini, "Working in Practice But Not in Theory: Theoretical Challenges of "High-Reliability Organizations," *Journal of Public Administration Research and Theory* 1 (1991): 30.

16. Charles Perrow, *Normal Accidents*, rev. ed. (Princeton: Princeton University Press, 1999).

17. Vaughan points out that although the Shuttles were reusable, thus superficially identical among existing craft and from mission to mission, in actuality, "no two shuttles were alike; after each mission, the several NASA/contractor work groups made hundreds of changes, so the technical artifact was different for each launch" (Vaughan, "Role," p. 919).

18. In a heroic but doomed effort to "predict changes in NASA satellite contracts," two management analysts secured a NASA grant in the early 1970s and profiled the contract changes for 21 satellite projects. Seeking a predictive formula, they ignored engineering changes below the contract change level (Engineering Change Requests, or ECRs, versus Contract Change Proposals, or CCPs [CCPs were often large-scale shifts in design, whereas ECRs usually were changes in individual components]), identified mean change costs as $100 K–$300 K, and struggled to find something to regress. Yet they did offer an empirical table that suggests the economic foundation for contests and alliances. Focused on 21 contracts between 1959 and 1968, it showed that in the course of the first 10 contracts (1959–62), final costs were 5.1 times initial contract figures on average, though in the final 10 contracts (1964–68), this multiplier fell to 2.1. However, final costs were estimated in half the latter 10, as perhaps cost data

continued on the next page

endless Engineering Change Requests that testing and use generated meant routine contests both over the need for and design of reconfigured components, checkout routines, etc., and over who would bear the costs. Economically, as well, changes (due to incapacities or aimed at improving capabilities) escalated program expenses and generated NASA-corporate alliances between firms when both faced congressional appropriations hurdles. Primes and subs fought over late deliveries and defective products yet stood shoulder to shoulder against persistent NASA "meddling," "intrusive oversight," or "policing."[19]

Varied patterns of clashing cultures stretched back to the space program's earliest days, when, in the course of new and massive contracting for Mercury spacecraft, the inheritance by the Army Ballistic Missile Agency (ABMA) and NASA of "management by detail" from NACA/Peenemünde ran head-on into McDonnell's pride in engineering creativity and independence. Long a principal Air Force aircraft supplier, McDonnell expected a continuation of the arm's-length, consultative style of contract relations crafted over two decades. Instead, NASA designers and managers, who had never held responsibility for a major technologically novel project, locked horns repeatedly with industry specialists who *had* done so.[20] Later, when NASA Administrator James Webb geared up for Apollo in 1963 by reorganizing the Agency's top management, those he brought in had substantial experience in Air Force ballistic missile program management and industrial military contracting (George Mueller, Air Force Generals Samuel Phillips and Edmund O'Connor, and the legendary Joseph Shea).[21] Webb evidently recognized that at NASA, "nobody knew how to do program management or work with industry on large programs."[22]

---

continued from the previous page
remained incomplete at the time of their article's composition. The decline in the overrun due to contract changes does suggest better specifications in the latter period. See William Stephenson and Bruce Berra, "Predicting Changes in NASA Satellite Contracts," *Management Science* 21 (1975): 626–637, table on p. 629. Regarding Apollo, "what began as a $400 million contract would top out at $4.4 billion a decade later. But everybody knew this going in. All of the Apollo bids were smoke and mirrors, because [in 1962] nobody knew what they were talking about" (Gray, *Angle of Attack*, p. 120).

19. Regarding the Shuttle booster, Vaughan observes that NASA saw "Marshall engineering's role" as "policing Thiokol; to find fault, to identify mistakes, to make sure the contractor abided by the contract" (Vaughn, "Role," p. 920). The issue is not that this was not appropriate, but that it was inadequate and ineffectual.

20. Joan Bromberg indicated that NASA core leaders feared loss of design control and shoddy work by companies given too much authority. See Bromberg, *NASA and the Space Industry*, pp. 40, 43. See also McCurdy, *Inside NASA*, pp. 38–42, which includes this gem on p. 41: "In one celebrated instance, contract workers at what became the Kennedy Space Center went out on strike because the von Braun team would not let them alone. The workers were accustomed to Air Force practice, which involved little direct supervision."

21. Shea took personal responsibility for the Apollo fire disaster and resigned from NASA in July 1967 (Kelly, *Moon Lander*, p. 161).

22. McCurdy, *Inside NASA*, p. 92.

McCurdy's judgment on the results of this reorientation is clear: "NASA's success in achieving the goals of the Apollo program was due in large measure to the tension between the Air Force approach to program management and NASA's traditional technical culture."[23]

Organizational structures did create platforms for alliances, however fraught with tension, as well as for clashes. Industry and Agency engineers with similar specialties and backgrounds worked through problem sets in spaces far distant from policy-making and budget authorizations. For example, Space Task Group and McDonnell collaborated in depth to create Project Orbit, the huge vacuum chamber in which an entire Mercury capsule could be tested in as close to space conditions as was then feasible. Later, on the Lunar Lander project, NASA and Grumman co-staffed the Change Control Board to assess modifications and manage configuration (modeled on Air Force practice).[24]

4) Conceptualizing contracting relations and production on technology's edges.

Although these first three items hardly exhaust the potential list of themes linking NASA and industry, technology and organization, practice and process, design and production, it is worth pausing here for a moment to consider the possible conceptual tools and theoretical frameworks with which scholars can map this terrain in ways that increase our understanding. Two existing frameworks stand out, at least in my view: Stephen Johnson's close analysis of systems management's rise to dominion in NASA programs, drawing on Weber, Drucker, and the literature of "knowledge management," and Howard McCurdy's sociological approaches to organizational culture at NASA and its transformations. Johnson's work focuses closely on the struggle to achieve rational control over projects and heighten reliability through devising and enforcing rigorous procedures. McCurdy reaches into the extrarational world of the beliefs and assumptions that underlie (and at

23. Ibid. See also Mike Gray, *Angle of Attack: Harrison Storms and the Race to the Moon* (New York: Norton, 1992), pp. 50–52. On p. 50, for example: "Most of [NASA's] key people were creative iconoclasts like Maxime Faget, conceptual thinkers used to a hands-on approach in which they personally supervised every detail . . . . Now they were being asked to create the largest technical organization of all time."

24. Johnson, *Secret*, p. 128; Kelly, *Moon Lander*, p. 102. By contrast, the Apollo program's "powerful Change Control Board," created in 1967 after the astronauts' deaths, seems to have been entirely NASA-staffed, with George Low making final decisions on "changes proposed by NASA or the prime contractors" (Kelly, *Moon Lander*, p. 163). Johnson discusses the collaborative style of early NASA-industry management more fully in *Secret*, pp. 116–120. Superficially, that is, without specific research into the issue, it appears to me that collaborative NASA-industry design and engineering waned and NASA surveillance/policing increased over time, perhaps a shift triggered by the January 1967 deaths of White, Grissom, and Chaffee, as might be inferred from Johnson's review of the postaccident managerial shifts and conflicts (*Secret*, pp. 146–150). If there was such a shift, was it confined to manned space issues, or did it generalize across all NASA projects?

times undermine) practices, offering a dramatically different perspective. Both focus primarily on the Agency, as would be expected, leaving ample room for pursuing questions about the industry and production side of the spacefaring equation.[25]

Three other perspectives, which grapple with practice at the "local" level, strike me as potentially valuable, particularly in thinking about industrial matters:

1) Adapting the social construction of technology (SCOT) framework to encompass ways in which emergent organizations, much like "unruly" technologies, can become "uncertainty multipliers," a notion Diane Vaughan has applied convincingly to "the NASA/contractor organization" for the Shuttle.[26]

2) Exploring management theorists' conceptualization of the interplay between rationality and irrationality within organizations, and its relation to collateral inquiries into organizational disorder and its implications.[27]

3) Developing research questions in relation to work and technology, based on anthropologists' concern for "situated practice" and "communities of practice."[28]

The provocative potential of Vaughan's perspective can be quickly sensed in her opening remarks to a recent discussion paper on organizations and techno-scientific knowledge:

---

25. Johnson, *Secret*, pp. 1–3; McCurdy, *Inside NASA*, pp. 163–164. Johnson also includes an instructive comparison with the European space agencies (European Space Research Organisation [ESRO]/ELDO, *Secret*, chaps. 6 and 7) but does not appear to have delivered on one significant point. He ends chap. 5 (speaking of the period around 1970) with "The disadvantages of systems management would become apparent later . . ." (pp. 152–153), but so far as I can tell, no discussion of disadvantages appears in the remaining sections of his study. There may be other theoretical frameworks well exemplified in NASA literature, but I'm not yet familiar with them. Both McCurdy and Johnson undertake the explanation of NASA's "decline" and the resurgence of mission failures/disasters two decades after Apollo.

26. Vaughan, "Role," pp. 916–919. Vaughn's inspirations flowed from Clifford Geertz, Charles Perrow, and the "situated action" group (n. 27), as well as from the STS and science studies literatures (see "Role," pp. 935–936, nn. 2–5, 17).

27. Nils Brunsson, *The Irrational Organization: Irrationality as a Basis for Organizational Action and Change* (New York: Wiley, 1985); Massimo Warglien and Michael Masuch, *The Logic of Organizational Disorder* (Berlin: deGruyter, 1996), esp. the editors' introduction and chapters by Bruno Bernardi, Erhard Friedberg, and Nils Brunsson.

28. Lucy Suchman, *Plans and Situated Actions* (Cambridge: Cambridge University Press, 1987); John Seely Brown and Paul Duguid, *The Social Life of Information* (Boston: Harvard Business School Press, 2000); Julian Orr, *Talking About Machines* (Ithaca: Cornell University Press, 1996); Christian Heath and Paul Luff, eds., *Technology in Action* (Cambridge: Cambridge University Press, 2000); Etienne Wenger, *Communities of Practice: Learning, Meaning and Identity* (Cambridge: Cambridge University Press, 1998).

> I begin by drawing on organization theory to illustrate the central paradox of organizations: namely, that the characteristics usually associated with the bright side of organizations—the structures and processes designed to assure certainty, order knowledge, and stabilize operations, thereby making coordinated activity possible—also have their dark side—the capacity to generate uncertainty, disordered knowledge, instability and unanticipated outcomes . . . . [T]his paper targets the conjunction of organization and technology that affected the production of knowledge and knowledge claims on a routine basis [at NASA]. The paradox is illustrated by showing the variable effect of the NASA organization on the production of techno-scientific knowledge: 1) the production of disordered and uncertain knowledge on a daily basis; and 2) the fact-hardening mechanisms in place to convert disorder to order when a collective decision was necessary.[29]

Where Johnson sees systems management as generating reliability and certainty, by tracing *Challenger* and other failures to a relaxation of detail discipline,[30] Vaughan sees the ghost as inherent in the great machine and penetrates deeply enough into the everyday life of techno-science to establish that "disordered knowledge is a byproduct of the very organizational mechanisms designed to control it." "Structure creates pockets of meaning systems—distinctive local knowledges . . . —that are by definition contradictory . . . . Structure [also] obscures, so that actions occurring in one part of an organization cannot, for the most part, be observed by people in other parts." Her work echoes in organizational/knowledge terms Perrow's critique of technical complexity, urging that scholars acknowledge that everyday practices and relations have dangerously ambivalent implications for organizational and technical outcomes.[31]

If so, recognizing that nonrational dimensions to organizational and technical practice are routinely yet unevenly present in all action situations can be a valuable step. Nils Brunsson has memorably underscored the presence and significance of nonrational dimensions of organizational practice, especially in regard to innovation. From his perspective, planning creativity is as fruitless as creating a random search for a technical fault, precisely because different modalities of thought and practice inform decision-making versus action-

---

29. Vaughan, "Role," pp. 914–915.

30. Johnson, *Secret*, pp. 228–229, and n. 9, pp. 275–276. McCurdy debits such disasters in fair measure to the attrition of NASA's classic high-performance "technical culture," rising risk aversion, and a politicized intolerance for failure (*Inside NASA*, chaps. 5 and 6).

31. Vaughan, "Role," p. 916, both quotations; Perrow, *Normal Accidents*.

taking. Agents need perennially to be aware that overreliance on rationality can generate stalemates, just as overreliance on intuition and enthusiasm can yield chaos. One central insight Brunsson's exploration of the "irrational organization" offers is that agreement on goals makes conflict difficult to understand in complex environments, whereas failed conflict resolution (organization change) can generate "social deadlock," the outcome when "a group of people have arrived at a situation which satisfies none of them but which they are unable to change."[32] The relevance of these conceptualizations to analyzing patterns of and changes in NASA-contractor relations is hard to miss.[33]

Third, in their anthropology of work and practice, Julian Orr, Lucy Suchman, and their colleagues undertake to reemphasize the importance of informal structures and relations, and of the knowledge and routines they generate, to organizational activity. As Scott noted, even conceptualizations of organization-technology relations that stress contingency, hence situation/place and history "overlook the importance of informal structures as a response to uncertainty and complexity." These are bottom-up processes or, perhaps better, integrative linkages:

> Rather than augmenting hierarchies, they minimize vertical distinctions, and rather than creating new, specialized lateral roles and relations, they encourage more direct, face-to-face communications among any or all participants as required. Decision making and the exercise of control become more decentralized, and organizational roles less formalized.[34]

32. Brunsson, *Irrational Organization*, pp. 27, 97, 111. By bringing the irrational into the picture of "normal action," Brunsson generates an array of striking (and testable) insights, namely, "efficiency seldom goes hand in hand with flexibility" (p. 4); it is "important to recognize that decisions can exist without actions and actions without decisions" (p. 21); and that in high-risk situations, those undertaking to reduce uncertainty are "speculators in success" and those trying to lower the stakes at risk are "speculators in failure" (p. 52). The *psychological* dimensions of organizational action are key for Brunsson, and these cannot be reduced to rational propositions.

33. Here's one minor story that shows the power of the nonrational in NASA-business relationships. In early 1963, NASA and North American representatives met 15 hours a day, six days a week in Houston to "hammer out a specific agreement on what North American was going to build and what NASA was going to pay for" in the Apollo program. Yet the NASA team was woefully underexperienced in negotiating contracts. As a NASA designer reflected, "We ought to have known better at the very outset . . . . Not any one of [our] technical guys knew a damn thing about costing. They had no basis to negotiate anything. We locked them up in these rooms [with North American managers and lawyers] and *most of them came out mortal enemies. That set a feeling that lasted a long time*" (Gray, *Angle of Attack*, p. 144, emphasis added).

34. W. R. Scott, *Organizations: Rational, Natural and Open Systems*, 3rd ed. (Englewood Cliffs, NJ: Prentice Hall, 1992), pp. 248–249, both quotations. An excellent ethnography based on this approach is Julian Orr's *Talking About Machines*. For a broader perspective, see Robert J. Thomas, *What Machines Can't Do: Politics and Technology in the Industrial Enterprise* (Berkeley: University of California Press, 1994), and Thomas Davenport, Susan Cantrell, and Robert Thomas, "The Art of Work," *Outlook Journal*, January 2002, *http://www.accenture.com/xd/xd.asp?it=enweb&xd=ideas%5Coutlook%5C1.2002%5Cart.xml.*

In American corporations and state agencies, uncertainty generates managerial hunger for top-down control, but few managers can master the massive knowledge requirements for its exercise, especially in situations where knowledge is emergent and distributed widely, as in complex contracting/subcontracting environments. Moreover, as Vaughan emphasized, the compression/reduction of vast bodies of information and the structural inability of capturing situated practice can readily transform control over uncertainty into a generator of illusion and disorder.[35]

NASA AND INDUSTRY: TWO KEY STUDIES

In identifying the themes and conceptual packages just outlined, both the insights and the silences of previous research bearing on production for NASA proved crucial. Thus far, works by Johnson, Kelly, McCurdy, and Vaughan have been emphasized; here, I'd like to consider the legacy of studies by Bart Hacker and Jim Grimwood (Gemini) and Joan Bromberg (NASA and space industries). First, however, a visit to the shop floor from Mike Gray's and Roger Bilstein's Saturn booster studies will set the stage for underscoring the extravagant technical demands and necessities for innovation that infused production for NASA.

The Apollo program's Saturn artifacts were the largest rockets fabricated in the U.S. in the 1960s (perhaps ever). Yet creating their components was enormously difficult; consider, for example, the propellant tanks for the rocket's lightweight S-2 first stage. Huge (reportedly three railway freight cars could be placed inside them) yet fragile (they couldn't be fabricated horizontally, but had to be built upright), they presented unprecedented challenges in welding. "At a time when a flawless weld of a few feet was considered miraculous, the S-2 called for a half mile of flawless welds." Moreover, the components for the tank's dome—"immense pie-shaped wedges of aluminum eight feet wide at the bottom and twenty feet from there to the apex"—were elaborate spatial forms, "a spherical curve from side to side and a complex double ellipsoid from the base to the apex." Given that no techniques existed for accurately machining such shapes, called gores, North American used explosive forming. Technicians placed the alloy blank on a forming die at the bottom of a 60,000-

35. Vaughan, "Role," pp. 926–934. This involves what Vaughan terms "fact-hardening," and the procedures for achieving it here rely substantially on the exclusion of qualitative information. As she notes, "Indeterminacy creates a closure problem." This is resolved by generating quantitatively structured documents and public consensus. "The documents . . . assert consensus through the matter-of-fact tone of the formal mode of discourse, affirming the reality they assert to both the audience and the author. An additional factor that binds people to their actions is 'going public.' When a person participates in and is identified publicly with a decision, that person will resolve inconsistencies to produce attitudes consistent with that choice." Quotations are from pp. 929 and 930.

gallon water tank, then set off a cluster of carefully placed charges on the surface. In an instant the force carried through/by the water pressed the blank into the die-form (trimming followed).[36] These segments in turn were welded by "a new kind of a machine":

> [T]he assemblers . . . were looking at a seam that followed a constantly changing curve over a twenty foot run, and the junction between the [gores] would have to match precisely to within a hundredth of an inch . . . . [T]he ultimate solution looked a little like a Japanese footbridge—a heavily reinforced bow-shaped truss that spanned the width of the dome and carried beneath it a precision track on which the welding machine traveled. The gear-driven welding head, its speed controlled by mathematical formulae, rolled ever so slowly up these rails carrying a tungsten electrode that precisely melted the metal on either side of the joint.[37] [See photo opposite; the footbridge welder is visible at the upper left.]

Thus were intricate demands addressed. Routinely for builders, no obvious means lay available to satisfy the interactive realities of technical complexity, technical uncertainty, and component interdependencies in production for NASA, thus propelling organizational frustration and technological creativity. This pattern is evident in each of the two other studies noted above, to which we now turn.

Industry-NASA relationships are especially prominent in the first 10 chapters of *On the Shoulders of Titans*, the segment authored by Bart Hacker. Like a number of jet engine projects a decade earlier, Gemini was the result of an effort to redesign an existing complex technological artifact, the Mercury capsule. By early 1961, James Chamberlain, Space Task Group's head of Engineering and Contract Administration, determined largely on his own initiative that the Mercury spacecraft needed a redesign "from the bottom up," and thus spent part of February in St. Louis going over possible revisions with McDonnell engineers. Modularizing systems that in Mercury "had been stacked like a layer cake" such that "components of [any] one system had to be

36. Gray, *Angle of Attack*, pp. 154–155.

37. Ibid., p. 156. This sequence is also carefully reported by Bilstein in considerably greater detail. See Roger Bilstein, *Stages to Saturn* (Washington, DC: NASA SP-4206, 1980; reprint, Gainesville: University Press of Florida, 2003), pp. 212–222 (page citations are to the reprint edition). For several of the hard-core technological issues, see W. J. Reichenecker and J. Heuschkel, *NASA Contributions to Joining Metal* (Washington, DC: NASA Technology Utilization Division, NASA SP-5064, 1967). This publication includes references to a number of North American reports, as well as reports from Marshall, Pratt & Whitney, Kaiser Aluminum, and others. The figure is drawn from Bilstein, *Stages*, p. 221.

Gores being welded to bulkheads for the S-II stage of the Saturn V. *(Source: Roger Bilstein,* Stages to Saturn *[Washington, DC: NASA SP-4206, 1980; reprint, Gainesville: University Press of Florida, 2003], p. 221)*

scattered about the craft" would "reduce manufacturing and checkout time," Chamberlain argued. Yet as Hacker summarized, "making it better meant making it over." Once Chamberlain and McDonnell's William Blatz collated the redesign elements, they went before the Capsule Review Board, which "seemed staggered by the scope of the changes presented to them" in June.[38] As in jets, what started as a fix, or more accurately, a vector for refining the artifact, morphed into a largely new device, yet here still a one-man capsule.

McDonnell engineers, led by Walter Burke, were the agents who outlined and pushed for the two-man spacecraft, however, as it was the builders who "were pressing for a more radical effort." Indeed, in undertaking the preliminary design work, "McDonnell had not felt obliged to wait until its contract had been amended to provide the extra funds. The company spent its own money," which generated "a good deal of respect in NASA circles." As major spacecraft contract changes arose in order to expand its size, handle

38. Hacker, *Titans*, p. 33–45.

modularization, and create a docking system and (initially) ejections seats, expectations for reusing Mercury technologies in the new developmental trajectory faded as steadily as the project drove forward. This momentum and focus on industry relations were aided by an organizational arrangement which provided the Gemini Project Office and Chamberlain "a degree of autonomy," enabling them "to deal directly with McDonnell and Air Force Space Systems Division" for capsules and boosters respectively. Chamberlain reported only to Marshall Space Flight Center Director Gilruth, chiefly providing him work in process reviews and discussions from coordination meetings, "Gemini's central management device."[39] Thus far, an organizational device giving Chamberlain singular authority (how unusual? with what exact options? how evaluated by Headquarters and by McDonnell?) and decisive redesign innovations from industry engineers and engineering managers facilitated Gemini's emergence.[40]

However, a series of technological disappointments, cost escalations, and budget controversies soon caused massive headaches. In some measure, these derived from the fact that McDonnell "developed and built only the spacecraft structural shell and electrical system"; all else had been subcontracted. Thousands of components made by hundreds of firms flowed into St. Louis; if Gemini mirrored Mercury in this respect, an unknown, sizable subset of those devices would fail on test, fail to meet specifications, or fail to integrate effectively, and thus would need to be redesigned or replaced.[41] In a retrospective overview, Hacker reflected, "Although the precise nature of

39. Ibid., pp. 49–82, 95. Even as expectations faded that technical apparatus from Mercury could be duplicated in Gemini, major continuities in personnel between the two programs proved a strength, from Faget, Gilruth, Chamberlain, and McDonnell's Walter Burke down to the shop level, where, for example, NASA plant representative Wilbur Gray shifted gradually from Mercury to Gemini. Gray's memos and reports are a marvelous source for reconstituting, in part, the informal relations and emergent communities of practice mentioned earlier in the essay. Chamberlain's autonomy may have been modeled on the direct relationship NASA's Max Faget and McDonnell's John Yardley had in making "thousands of detailed design decisions" on the Mercury capsules. See Loyd Swenson, "The 'Megamachine' Behind the Mercury Spacecraft," *American Quarterly* 21 (1969): 210–227, quotation from p. 222.

40. This approach in no way intends to overlook issues and pressures *external* to the Gemini project, such as the uncertainties about Apollo's developmental trajectory, funding, and schedule, or the cultural/political pressure to keep performing launches as Mercury was beginning to wind down.

41. Archivists at NARA–Fort Worth indicated that the boxes on technical testing and subcontractor relations I was using in my NASM/Lindbergh-supported research had not previously been pulled. Swenson's *This New Ocean* understandably did not penetrate to this level of source material, some of which, it appears, had not yet been archived or declassified at the time of its writing. NASM's Michael Neufeld suggested to me that the view among space historians is that Gemini was a much less troublesome project than Mercury, due to technological and organizational learning. This is a position that might merit further probing, although Hacker did drive more deeply into industry/production documents than did Swenson (Hacker cites telexes, letters to contractors, and activity, status, and "tiger team" reports, for example).

Gemini's problems could not have been predicted, they did arise *where* they were expected—in those systems that demanded the greatest advances beyond current technology."[42] This is such a basic point that it is worth reinforcing—*innovation generates disorder, and dramatic innovation entails error, failure, and conflict across a broad front*. In some technological environments, a stabilization follows, both of knowledge and technology. When additional requirements are promulgated, extensions of capability are feasible on the basis of retained learning and scalable technique, though the achievements usually are hard-won. In other situations, workable innovations do not provide a foundation for enhancing capabilities, which is to say that stabilization proves illusory and learning less than readily applicable to upgrading. These often involve nonscalable technologies, which are the home for hordes of unk-unks and the sources of persistent frustration and failure in large technological projects.

Two Gemini examples merit recounting: the fuel cell innovation and the recurrent issues surrounding thrusters—both involving subcontractors, here General Electric and Rocketdyne. Fuel cells had the potential to replace batteries as the source of on-board electricity, at a major savings in weight. However, in Gemini, the array of problems cropping up "seemed to suggest that theory had outrun practice." GE researchers knew scientifically that the reaction of hydrogen and oxygen could generate power, and they had devised a clever "solid, ion-exchanging membrane" that dramatically simplified both the device and its operation. Unfortunately, this science-led technology did not operate successfully—the membrane leaked, weakening output, and once this fault was corrected, the cell exhibited "degraded performance" once activated. Technicians traced this to the shortcomings of a fiberglass component and replaced it with a Dacron substitute, which triggered new troubles. Other test failures derived from the cracking of the cell's titanium tubing; these were replaced with a titanium-palladium alloy. Further problems appeared, but they "were never conceptual . . . . The rub came in trying to convert [the] concept into hardware to meet the Gemini specifications." After two years' work, NASA canceled the effort in January 1964, resumed work on battery development, and spent $600,000 to retrofit two capsules outfitted with fuel cells. The same pattern recurred soon after, with the Apollo Moon lander's fuel cell program (this time handled by Pratt & Whitney) canceled early in 1965 following two years of trials and failures, with reversion again to batteries.[43]

Thrusters presented an enduring difficulty. Twice in the Mercury program, their fragility and unreliability caused serious concern. In January 1962, McDonnell was testing Capsule No. 2's Reaction Control System when the

42. Hacker, *Titans*, p. 162.

43. Ibid., pp. 103–104, 148–152. For the LEM story, see Kelly, *Moon Lander*, pp. 82–84.

base of the spacecraft caught fire due to leaking thruster propellant, which, when it combusted, caused further leaks, more combustion, and quite a bit of damage to the artifact and to the designers' confidence.[44] Just a month later, during John Glenn's orbital flight, the Automatic Stability Control System, which coordinated the thrusters to maintain proper attitude, went for a walk over Mexico. Glenn explained:

> The capsule started drifting to the right in yaw and it would drift over to about 20 degrees, instead of the normal 30 degree limit, and then the high thruster would kick on and bat it back over to the left. It would overshoot and then it would hunt and settle down again somewhere around zero. The spacecraft would then drift again to the right and do the same thing repeatedly.[45]

Glenn put the system into manual control (then into fly-by-wire), which saved fuel, but the capsule began to yaw to the left, and it was soon apparent that "there was no left low thrust."[46] Glenn discussed how he dealt with the inoperability problem:

> When the fly-by-wire one-pound thruster was not actuating in yaw, I was using a real fast flip of the high thruster in the mode that the one-pound thruster was not operating to control. I couldn't control this as accurately as you can with the one-pound thruster, . . . so what I did several times was, when I would overshoot in rate with the 24-pounder, I would use my one pounder on the other side to bring it back to zero . . . I wouldn't call this desirable.[47]

Unsurprisingly, attention to thruster testing and possible design flaws increased sharply.

With the more ambitious Gemini program's development, thruster problems became more acute and challenging. The smaller of the two propulsion units on Gemini was roughly the size of Mercury's larger unit (25 pounds of thrust), whereas Gemini's big pusher was to yield three times that power (85

---

44. R. H. Lilienkamp, Senior Engineer, McDonnell, "Investigation of the Capsule No. 2 Incident, 9 January 1962," 16 January 1962, MAC Technical Reports, box 27, entry 198C, NASA-JSC, NARA RG 255.

45. R. B. Voas, "Memorandum for Those Concerned, MA-6 Pilots Debriefing," pp. 13–14, Contract Administration Files, box 31, entry 198E, NASA-JSC, RG255.

46. Ibid.

47. Ibid., p. 61.

pounds). The Mercury components had simply managed attitude control; in Gemini, they had to handle spacecraft maneuvering and in-orbit rendezvous. Third, the Gemini fuel was different—monomethylhydrazine and nitrogen tetroxide, which combusted on contact, versus Mercury's simple hydrogen peroxide, which expanded radically on release under pressure. Last, and most troublesome, whereas the Mercury thrusters operated for a few seconds at a time, Gemini's would need to burn steadily for 5 minutes or more, as well as to pulse repeatedly.

The bad news came in waves. Tests early in 1963 showed that the 25-pound Geminis tended to "char through their casings" when run continuously. A redesign at first seemed to remedy this, but pulse testing proved half again more destructive to the casings, and a series of "expedients . . . could only alleviate, not solve, the problem." Most troubling, the nonscalability gremlin soon surfaced, as "new tests revealed that the larger maneuvering thrusters could not be simply enlarged versions" of the 25-pound engines. Therefore, a separate design and testing program for them had to be devised. In October, the hammer dropped—mission simulations showed that astronauts used their thrusters far more than had been anticipated—thus, "thruster life would have to be doubled or tripled."[48]

Rework lasted well into 1964, with the result that Rocketdyne fell far behind schedule and had spent more than double its allotted $30 million. NASA soon demanded a "full scale" audit, which revealed a "badly managed program," for the company had "grossly underestimated the magnitude and complexity" of its engine subcontract. Fewer than half the engines slated for delivery by November 1964 had been received, and McDonnell was far from confident in the thrusters' reliability. Still, by mid-1965, Rocketdyne had reorganized the engine division, recovered its momentum, and begun to meet or exceed schedule expectations.[49] The facts that different-sized and differently purposed engines could not be scaled up or down from existing, workable models and that elaborate fueling and combustion systems were inadequately understood meant that propulsion surprises would continue to arise.[50]

Technological problems solved for a mission having certain requirements did not necessarily spill over to later missions with more demanding require-

48. Hacker, *Titans*, pp. 83–84, 154–157. The upgraded demands settled at over 9 minutes for the small thrusters and over 13 minutes for the large.

49. Ibid., pp. 210–211. This happy outcome did not prevent thruster problems from arising on three missions—Gemini V, VII, and VIII. See ibid., pp. 259–260, 292, 314–315.

50. One of the key dilemmas here was combustion instability, which arose when flows of fuels (and oxidizers) failed to generate a steady, focused flame thrust, whether due to cavitation, component performance problems, or other factors. Correcting such instability once it occurred seemed impossible, for the effects were dramatic and instantaneous on missile attitude and trajectory, nor was the science of fluid dynamics sufficiently developed to model these flows mathematically and continuously.

ments. The organizational approaches effective for solving first-generation dilemmas would not assuredly suffice for next-generation challenges. As well, the insufficiencies of science regarding critical, complex phenomena (combustion and fluid dynamics, materials performance under zero gravity, etc.) meant that workable engineering outcomes could not be stripped of their anxiety dimensions, for, as with Mercury, components that worked 10 times could (and did) fail on the 11th, without warning and without obvious (or remediable) cause.[51] In this light, it would perhaps be worthwhile for researchers to explore those domains in which basic science guided NASA technical practice, those where NASA practice extended scientific knowledge and theory, and those where the two remained disconnected in specific situations or for longer periods.

Moving to the industry-NASA relationships depicted in Joan Bromberg's pioneering overview entails a shift in focus, for her work undertakes a long-term analysis. This essay is anchored in thinking through technology and production issues, whereas after its opening sections, *NASA and the Space Industry* (*NSI*) moves toward the second of its two themes—space and the marketplace, for satellites, Shuttle usage, et al.—if you will, the consumption side of NASA. Nonetheless, *NSI*'s first theme, "the innovation process," is clearly germane. Here, Bromberg delineates production for NASA's crucial background conditions, identifies core tensions, and offers two detailed case studies of innovation—satellites at Hughes and Apollo at North American.[52]

Four background items Bromberg highlights are particularly rich with implications:

1) Lockheed's science crisis in the mid-'50s "over whether scientists on a project should have control over advanced development." The firm said no; 15 top scientists left, frustrated that their demand to direct work for which "the skill and technical knowledge [was] beyond the state of the art" had been rejected. Science-engineering and scientist-manager relations are a subplot in NASA-industry relations, though, as a novice, it's not clear to me how much these have been investigated.

51. As Hugh Dryden stated in the closing Project Mercury Conference, "We learn how to build things to last longer by trying to build them, by operating them in space, finding out what goes wrong, correcting, learning more about the environment . . . . These are things that we learn by going into space and working there, not from some theory in the laboratory" ("Mercury Final Conference," pp. 1–2, box 1, E196, RG255).

52. At the outset, Bromberg refers to technical professionals' "community of practice" but does not seem to be aware of the communities of practice in literature and research approaches noted here in the section on conceptual frameworks. In a discussion with NASM's Martin Collins (13 January 2005), I came to appreciate that oral history interviewing below the executive level (planned but never completed)—interviewing of design, test, and production engineers, for example—would, in framing novel questions, profit substantively from familiarity with the work of Orr, Suchman, and Lave, and also from thinking closely about Karl Weick's challenging *Sensemaking in Organizations* (Thousand Oaks, CA: Sage, 1995), especially in relation to puzzles, failures, and conflicts over knowledge, interpretation, and practice.

Here, did those resigning create their own firm; move to universities; seek research unit jobs at Mellon, Battelle, or RAND; hire on to other industrial firms; or what? Did such confrontations appear on aerospace's technological edge with some frequency, or was this a rare moment?[53] After all, the role of science and scientists in NASA work is not so obvious at it might seem, given the huge holes in scientific understanding of space environments in this era.

2) The Air Force's creation of Ramo-Wooldridge as a systems engineering and technical management firm (1954). To be sure, this laid the foundation for "weapons system" development and for TRW, but to what extent did valorizing this cluster of sophisticated experts create a template helpful for defining NASA's differences from NACA? Clearly the Air Force was already a contested model in terms of innovation management, so was NASA, in a slightly twisted organizational-lineage sense, Ramo-Wooldridge's unacknowledged or ungrateful offspring?[54]

3) The mid-'50s conflict between the Naval Research Lab and Martin, which prefigured scores of subsequent contretemps. In Project Vanguard, Martin argued that it should be provided "full [technical/managerial?] responsibility," while the NRL demanded the inverse. Martin claimed that the Lab was full of busy fault-finders, "always promoting the 'better' at the expense of the 'good enough,'" whereas the NRL asserted that Martin didn't "grasp how much they were dealing with unknowns, nor the importance of reliability . . . ." This contest, arrayed in just about these exact terms, would be replayed for several decades in NASA-industry relations, so what are we to learn from this early incidence? Was it *that* early, that is, was this just an extension of Navy "control-freakish" patterns, inverse to Air Force (and Army Air Force) delegation of project responsibilities to contractors? Was this "divide" a structural fault in postwar military/space programming, and was it ever resolved? If so, how? If not, with what implications? Or is this whole scenario just an outsider's confused view of the unfolding game?[55]

4) The Army's arsenal system (after its separation from the new Air Force) could not run all its ballistic missile projects inside von Braun's shop, simply because "it did not have the manpower." So was the arsenal system chiefly a managerial/operations framework and, in fair measure,

53. Bromberg, *NSI*, p. 25.
54. These relationships are sketched in Mueller Interview No. 4. See also Bromberg, *NSI*, pp. 26–28.
55. Bromberg, *NSI*, pp. 26–28.

> a hollow production system? Did shortcomings in securing adequate manpower (engineering, production, testing?) preview the complexities of producing for NASA? Did contractors learn from ABMA that they needed to resist control moves from their funders in order to protect opportunities for enhancing their own engineers' capabilities? Did "the enmity between the Army and the aircraft industry" bleed through to the space industry–NASA relationship, and if so, to what extent and with what consequences?[56]

Bromberg also details key drawbacks and advantages for companies undertaking production for NASA. On the downside were the small numbers of artifacts ordered, the necessity for expensive experimental development and research (some of which would be self-funded), demands for higher precision than usual in aeronautical engineering and fabrication, and the need to find and hire ever more engineers (and high-skill shop workers). Still, the pluses were substantial, if somewhat more vague: the "chance to learn technologies, develop skills and install production tooling that they could use for other projects," possible spillovers into commercial products, and the excitement of joining the space-race culture.[57]

She also shows that the bases for strain were quite concrete. If industry representatives in the 1950s saw "NACA engineers . . . as researchers, people whose aim was the production of papers and books," the incoming NASA leadership was equally critical. Given the necessity of contracting, Headquarters feared the loss of design control, shoddy work by contractors given too much leeway, and the loss of collective memory (and identity) as project teams formed and disbanded. Specifically in the Mercury capsule case, "Langley engineers mistrusted industry's ability to design something as novel as a spacecraft," whereas "industry and the military were convinced they knew more about space flight than NASA did."[58] This last item, the industry-military connection, reinforced NASA's uncomfortable position as the national novice in major project development and operations. Max Faget may well have had an advantage in being able to conceptualize a blunt-body spacecraft, but McDonnell's Walter Burke and his Air Force Material Command colleagues had learned firsthand how to fabricate complex aerospace technologies, as had von Braun and ABMA. Last, NASA might have considered industry folks immature and arrogant, but, as Bromberg so neatly puts it, "arrogance in proposals is also one of the channels by which creative ideas flow from industry to government."[59]

56. Ibid., p. 29.
57. Ibid., pp. 38–39.
58. Ibid., pp. 32, 43.
59. Ibid., p. 43.

When introducing the first of her two case studies (Hughes and satellites), Bromberg poses seven questions which articulate the chief concerns and boundaries of the study, "the relation between U.S. industry and the federal government."[60] Except by inference, none of these questions spotlight the technologies themselves, their design, prototyping, testing, redesign, fabrication, plus the consequent interfirm and contractor-government linkages. One technological-process moment appears when the failure of the first Syncom satellite was traced to a ruptured "gas tank," a problem "corrected" after a "search for a stronger material." The second Syncom "functioned brilliantly," but further questions that might have probed this failure and correction fell outside the study's scope.[61] This set-aside resonates with W. D. Kay's concern about the literature's silences on "the internal workings of the nation's aerospace contractors."[62] It remains for future scholars to address how Hughes designed and built its first three satellites; what the firm learned thereby and through what process; what innovations it embedded in the following four INTELSAT IIs; what machinery, materials, engineers, workers, consultations, conflicts, and compromises were involved.[63]

Similarly with North American, Bromberg's analysis works at the level of policy and program, though the secondary sources drawn on (especially Bilstein) yield a greater frequency of references to technical competencies and fabrication challenges. Thus the confrontation between Air Force General Sam Phillips (working for NASA) and North American leaders over "inadequate engineering, poor fabrication quality, faulty inspections, and cost escalations," all leading to delays and rework, is concisely reviewed, yet the underlying reasons for these multiple failures are not divined. As Bilstein, Kelly, and, to a degree, Mike Gray (*Angle of Attack*) demonstrate, in-depth technical review, appropriately contextualized, generates complex, contingent, and real-time analyses of innovation, critical insights and errors, integration, and technological and organizational learning.[64] This is, however, very difficult without

60. The questions are, "How much of the research for the commercial communications satellites would be financed, directed or done by government, and how much by the private sector? Would a private industry arise to launch the satellites or would they be launched by government? Would industry or government own and operate the systems? . . . What private firms would enter into the manufacture and the operation of commercial satellites (comsats)? What strategies would they use to gain market share? How would government policies and actions affect the market positions of private companies? How would these policies and actions affect the technology that was chosen?" (ibid., p. 46).

61. Ibid., p. 53.

62. Kay, "NASA," p. 127.

63. Five years ago, I did an online database search for articles in scholarly and technical journals on the design and fabrication of satellites, which then yielded fewer than a dozen hits. I expect a repeat these days would do much better, although the silences on building aerospace technologies may continue to include these devices.

64. An exceptional source in this regard is Martin Collins's series of interviews with North American Aviation's Lee Atwood, which document the critical role of NASA's detailed oversight in generating

continued on the next page

archival research, which, given its parameters and resources, was not plausible for this study.

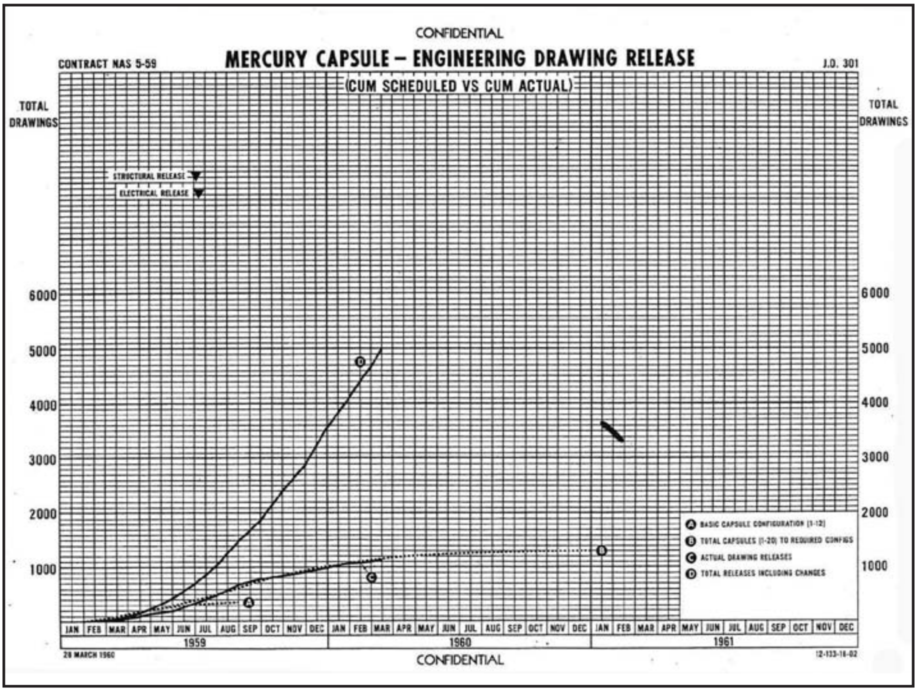
Nonetheless, Bromberg skillfully reviews the fabrication and engineering practice changes that followed the Apollo fire deaths: separate managers for each spacecraft, heightened attention to quality control, frequent shop-floor visits (including during night shifts), tightened change controls, along with some of the dilemmas their introduction created. "All changes now had to be funneled first through the program officer at Houston, and then through the manager of that particular spacecraft at NA Rockville. North American engineers were made to adhere rigorously to agreed-on procedures, without any creative flourishes." Moreover, NASA's increased surveillance and micromanagement necessitated hiring hundreds of inexperienced technical managers who knew far less about their programs than those they were overseeing, which in turn led to mechanical rule-following and conflicts, very much on the pattern that Vaughn's conceptualizations outline. Pursuing these issues deeply into archival materials, especially those surrounding the astronauts' deaths and their aftermath, could provide valuable understandings of a critical transition in America's space program.[65]

INDUSTRY AND NASA: MERCURY MOMENTS AND CLOSING QUESTIONS

Scattered about earlier pages are some items derived from my archival work with NASA Mercury sources. I'll mention just two others here focusing on a single matter, engineering changes, and will end by offering questions on other issues which may take on a fresh significance when researched from the contractors' technology and organization viewpoint. These items and issues may have more significance to historians of technology and enterprise (who

continued on the next page
masses of change orders and consequent delays and establishes the distinction between projects that were just complex (such as the Apollo Command Module) and those that involved "technological stretching," which ventured into the unknown. (See NASM Oral History Project, Atwood Interviews, no. 4, pp. 3, 10–11; no. 5, pp. 12, 14; no. 6, p. 3; available at *http://www.nasm.si.edu/research/dsh/TRANSCPT/ATWOOD4.HTM*, *http://www.nasm.si.edu/research/dsh/TRANSCPT/ATWOOD5.HTM*, and *http://www.nasm.si.edu/research/dsh/TRANSCPT/ATWOOD6.HTM*.) It appears that this is the only interview with a contractor official. It would be valuable were someone or some institution to take up Collins's plan for interviews with contractor engineers (and perhaps shop workers) before it is too late to target these sources of work and technology information.

65. Bromberg, *NSI*, pp. 70–73, quotation from 71. NASM's Alan Blinder is currently researching the Apollo 204 fire. For the industry perspective here, Bromberg cites a pamphlet by John L. "Lee" Atwood, NAA president, from NASM's Oral History Working File. Deeply interesting is the extensive oral history interview itself, done by NASM's Martin Collins, noted above. (The first segment is at *http://www.nasm.si.edu/research/dsh/TRANSCPT/ATWOOD1.HTM*; links at each section's end take the reader to the next segment.)



Engineering drawing release for the Mercury capsule, March 1960. *(Source: NASA Contract Administration Files, Procurement Division, box 22, entry 100, RG 255, NARA-Southwest)*

very much need to integrate public-sector innovations and organizations into their private-sector worlds) than for NASA history purposes, unless/until the scope and conceptualization of NASA history shifts in the years ahead.

The figure on this page is a simple graph documenting the engineering drawing releases for the Mercury spacecraft project, from inception through 15 March 1960. Lines A and C indicate that based on component counts, McDonnell had estimated that roughly 1,200 drawings would be needed through early 1961, 500 for the basic configuration and another 700 to include different capsules' mission-specific requirements (e.g., an orbital spacecraft versus one for a ballistic flight). Yet in response to the flow of engineering changes inside the project's first year, the actual number of drawings released reached 5,000 (line D). What significance this volume of redesigns had for project development is evident in Lee Atwood's reflections on Apollo:

> Once your engineering output of drawings and specifications gets ragged as far as the schedule is concerned, everything else

> gets ragged . . . . An engineering change is really a recall of something that's been released. You stop it, recall your drawing, you get an instruction to change it, bring it back, and the shop is full of that . . . . The things that are most apparent are usually picked up [in] a couple of weeks' surveys, because everybody has some kind of a schedule. Are you on it? Are you not? Well, of course you're not, and the whole place looked like a wreck. It was stop orders, hold orders, missing parts, material procurement had to be modified in many cases.[66]

Change orders were also lightning rods for NASA-industry arm wrestling, as was plainly the case with the Apollo Command Module:

> [The CSM] commanded the attention of so many astronauts and so many other people, engineers from Houston and all that. They all had their ideas of how things should be arranged, how controls should be set up, and an awful lot of brouhaha over the actual arrangement [resulted] . . . . One of the astronauts said, in connection with that, "You know, we have a pretty strong union." And they really did. They really did. And Dale [Myers] had to face the problem of arrangement [changes,] plus electrical changes, which came from other parts of the stack and from the ground equipment itself . . . . So there were just infinite refinements and changes, more than the S-II, which was fundamentally structural, a weight problem, . . . whereas the impact on the command module was almost screw by screw, and estimate by estimate and switch by switch.[67]

Researching the dynamics, the politics, the language, and the practices regarding engineering changes, which had pervasive implications for scheduling, cost, and program/artifact reliability and success, demands moving deep within both NASA and contractor organizations, following plant representatives like Wilbur Gray from Mercury to Gemini, chasing the origins and resolutions of

66. Atwood Interviews, no. 5, pp. 10–11.

67. Ibid., p. 12. Elsewhere, Atwood added: "Your ideal is to engineer something, put it in the shop, get it built efficiently, and then inspect it carefully and get it out the door and operate. We had an environment that required us to do all those things at once, with much backtracking to make changes. The changes were almost overwhelming. So this was part of the problem of the organization, and it was far from normal. In fact, as Sam Phillips noted, it was to a considerable degree out of control. Parts had to go back for re-engineering, redesign, again and again, re-release, new material, supply and manufacturing and tooling. Yes, it was a struggle" (Atwood Interviews, no. 7, p. 3).

issues that surfaced briefly in configuration control committee minutes, and reconstituting the scale and significance of conflicts over payment for extra work, rework, redesign, supplementary testing and such. Only in this way will historians begin to understand the sadness behind Atwood's crisp aphorism: "If things are done well, NASA succeeded; if things are done poorly, the contractor failed."[68]

A chart issued on the same date as the drawings release graph accounted for the sources of engineering changes through mid-March 1960. I have not yet tallied the total of engineering changes with any precision, as there evidently were several levels of and procedures for requesting and reporting these. However, there were approximately 340 major "contract change orders" in roughly 30 months and at least 6,000 changes to the capsule components and configurations. Key dilemmas included communicating change implementations, authorizing changes, testing implications of changes on other components, identifying failure sources, and updating specifications to reflect changes.

The figure shows that nearly half the ECRs (Engineering Change Requests) emerged from deficiencies detected in testing, here components. A different class of failures, "interferences," was noted under "Manufacturing Coordination," and at that date, my sense is that these were still physical impingements due to the "spaghetti" style of packing in capsule system components. When full capsule testing commenced, a third sort of testing deficiency appeared—system integration and interface problems. These took on yet further ramifications when capsules connected to boosters and to launch-related ground equipment displayed higher-order integration deficiencies. Together, tests and coordination problems represented nearly two-thirds of the ECRs, with improvements, including the famous astronauts' demand for a window, another one-fifth. Engineering studies, the work closest to scientific research, were handled both by NASA Centers and by McDonnell. What significance and impact these studies had on the project is not yet clear, nor do summary documents provide cost figures for the four classes. Still, this simple chart suggests that, from the beginning, waves of engineering changes flowed through manned space projects from multiple directions, generating specialized knowledge, urgent workarounds and overtime labor, unpredictable cost and schedule implications, and fluctuating currents of disorder.[69] In sum, retelling NASA stories from the drafting room and shop floor outwards, from the bottom up, has the potential to reorient a universe of NASA-centric histories.

68. Atwood Interviews, no. 4, p. 11.

69. Originals of these two figures may be found in CCP Status Reports, box 20, NAS 5-59, Contract Administration Files, entry 100, NASA-Mercury, RG255.

If such a scheme were to be activated, questions and issues like these, some of which reiterate points sounded earlier, would be tabled, all considering change over time, 1950s–1970s, at least:

1) How were relationships between design revisions and manufacturing practice articulated, in the dual-pressure contexts for extensive changes on one count and design freezes and standardization on another?

2) What implications did NASA contracts have for manufacturers' recruitment, training, and retention of highly skilled workers—engineers, shop-floor workers, and managers—for manufacturers' procurement of machinery and facilities?

3) Considering relationships between primes and subcontractors, what patterns and variations in knowledge exchange, mentoring and monitoring, financial management, etc., emerged in NASA contracts? How were these different from such patterns in military contracts? In commercial contracts? How did they differ when technological stretching was at issue, beyond "routine" complexity?

4) What spatial patterning eventuated in early NASA prime and subcontracts, and did this change? If so, how/when/why? What factors conditioned these outcomes (labor supply, proximities and networks, politics)? How did technological change in communications, creating virtual proximities, affect the spatiality of producing for NASA?

5) How did NASA's fabricators frame practices for identifying/processing/testing new materials, including a) uses in prototyping, b) developing supply lines (titanium being a classic case), and c) adapting existing or creating novel manufacturing procedures? What prior experiences with materials substitution (alloy metals, synthetics) conditioned this process versus what new trajectories of technical knowledge-seeking did the devising of aerospace materials articulate?

6) What historically tested production skills and practices were installed/modified/rejected as shop-floor experience in producing for NASA developed? What occasions for technological learning proved crucial to overcoming obstacles to fabrication, precision, or quality? (Consider candidates like chemical milling, explosive forming, numerically controlled tooling, et al.) What implications for further manufacturing practice did these adaptations/adoptions have, and to what degree were they realized? What conflicts between contractor managers and engineers resulted, between managers/engineers and workers, with what outcomes, including strikes? (N.B.: aircraft/aerospace manufacturing had one of the highest union densities in U.S. manufacturing, 1950–1990.)

7) What would be the breakdown of sources for delays and cost overruns; how would these differ among projects, and why? What links and learning trajectories can be established among projects from the contractors' side—evidence for and significance of knowledge-sharing among aerospace rivals—in terms of materials, electronics, or fabrication shifts? What internal and networked transfers of know-how among projects took place, and how significant were they?[70]

8) What arrays of managerial techniques did contractors deploy in efforts to comprehend and influence fabrication projects that, as Atwood testified, threatened to spin out of control? How did firms assess internally the competence of their production efforts, and to what degree did these evaluations correspond with those authored by NASA overseers? How did such Venn diagrams differ among projects, both over time and across artifact classes?

9) How did primes and subcontractors integrate producing for NASA into their enterprises' overall operations, and how was this integration (or lack of it) evidenced by corporate planning processes, capital funds allocations, career tracks, etc.?

10) What informal practices did contractors' employees devise, at each locus and level of institutional activity, to deal with (make sense of) the persistence of insufficient knowledge, the nonlinearity of testing and performance outcomes, the ubiquity of uncertainty, the stresses of complexity, and the nonrational character of creativity? To what degree were such practices formalized in training procedures or, alternatively, concretized, either spontaneously or in a planned way? Most broadly in this arena, how can we assess the human cost of aerospace innovation to individuals, families, and communities (both of practice and of residence)? How do these practices, trainings, outbursts, quits, and implications compare and contrast with those which materialized in commercial-market enterprises and institutions? Ultimately, how (and to what extent) can producing for NASA be integrated into the experience of American business in the

70. Weick makes a provocative comment regarding Westrum's "fallacy of centrality" (the phenomenon of discounting new information because if it were important the individual/organization would already have heard about it): "It is conceivable that heavily networked organizations might find their dense connections an unexpected liability, if this density encourages the fallacy of centrality. 'News' might be discounted if people hear it late and conclude that it is not credible because, if it were, they would have heard it sooner. This dynamic bears watching because it suggests a means by which *perceptions* of information technology might undermine the ability of that technology to facilitate sensemaking. The more advanced the technology is thought to be, the more likely are people to discredit anything that does not come through it. [Thus] the better the information system, the less sensitive it is to novel events" (*Sensemaking*, p. 3, emphasis in original).

Cold War decades, the social life of organizations, the construction of knowledge, and the history of technologies?

These, and surely other, open questions flow from this very partial review of literature and documents concerning NASA-industry relations. Along with the foregoing thoughts on key issues, plausible conceptual frameworks, and implications drawn from that literature, they are offered for reflection and reaction. Perhaps they will encourage what seems a long-overdue vector for research into the distinctive, little-understood world of production for NASA, which exemplifies the intensities, urgencies, joys, and miseries of high-tech, high-pressure, state-sponsored innovation.

Chapter 7

NASA and the Department of Defense: Enduring Themes in Three Key Areas

Peter Hays

As with any large government bureaucracies with imprecisely delineated areas of responsibility and potentially overlapping missions, the quality and productivity of the relationship between the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) have waxed and waned over the years. The NASA-DOD relationship has been shaped by a series of fundamental issues and questions that accompanied the opening of the Space Age, as well as by subsequent organizational structures, domestic and international politics, technology, and the personalities of key leaders. It is also helpful to consider these relations in terms of the three government space sectors and the bureaucratic roots and culture of the organizations created or empowered to perform these missions: the civil space sector for science and exploration missions performed by NASA, the intelligence space sector for intelligence collection from space by systems procured and operated by the National Reconnaissance Office (NRO), and the defense space sector for military missions enhanced or enabled by space systems procured and operated primarily by the Air Force.[1]

Although relations between these predominant space organizations have usually been quite harmonious and served the United States well, this analysis focuses more attention on periods of uncertainty or tension among these organizations in order to highlight enduring themes that were, and sometimes remain, at stake. Three key issue areas and time periods are examined: organizing to implement America's vision for space in the 1950s, wrestling with the rationale for human spaceflight in the late 1950s and early 1960s, and finding the logical next steps in space transportation and missions in the 1980s. The state of relations between the three predominant space organizations is also an important factor in shaping current issues such as how best to organize and manage national security space activities or implement the President's Vision for Space Exploration.

1. The fourth space sector, commercial activities for profit, is regulated by but not performed by government. See the comprehensive discussion of the activities included in each sector in *Report of the Commission to Assess National Security Space Management and Organization* (Washington, DC: Commission to Assess National Security Space Management and Organization, 11 January 2001), pp. 10–14.

DEVELOPING, ORGANIZING, AND IMPLEMENTING AMERICA'S SPACE AGE VISION IN THE 1950S

Following a long and difficult path, the United States Air Force was created as a separate service as a part of the National Security Act of 1947. Its raison d'être was strategic bombing, a mission that had enchanted airmen almost from the inception of flight, provided the foundation for the doctrine that guided America's use of airpower during World War II, and was of even greater concern following the advent of nuclear weapons. The Air Force was organized, trained, and equipped to provide a full range of airpower missions, but strategic bombing, the Strategic Air Command, and bomber pilots formed the institutional core of the new service. The development of long-range ballistic missiles and space systems presented difficult cultural challenges for the Air Force. These new systems held the potential to perform or support the Air Force's core strategic bombing mission, and the service was eager to develop and operate them rather than have them come under the control of the Army or Navy. At the same time, however, the new systems clearly threatened the bombers and bomber pilots at the Air Force's institutional core. The Air Force attempted to walk a difficult organizational tightrope through this situation by pursuing missiles and space strongly enough to keep them out of the grasp of the other services, but not so strongly as to undercut the bomber pilots who ran the service. This Air Force balancing act helps to explain much of its behavior at the opening of the Space Age and continues to be a useful illustration of its ongoing struggles to incorporate space most appropriately in its current and future missions.[2]

Space issues were not primary concerns in the wake of World War II, but America quietly struggled with many questions associated with why it should attempt to go to space and what it might do there. By the mid-1950s, a number of groups and individuals had advanced various reasons for going to space,[3]

2. On the evolution of air- and space-power doctrine and their role in Air Force institutional culture see, in particular, Phillip S. Meilinger, ed., *Paths of Heaven: The Evolution of Airpower Theory* (Maxwell Air Force Base [AFB], AL: Air University Press, 1997); Bruce M. DeBlois, ed., *Beyond the Paths of Heaven: The Emergence of Space Power Thought* (Maxwell AFB, AL: Air University Press, 1999); Carl H. Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force* (New Brunswick, NJ: Transaction Books, 1994); James M. Smith, *USAF Culture and Cohesion: Building an Air and Space Force for the 21st Century*, Occasional Paper 19 (U.S. Air Force [USAF] Academy: USAF Institute for National Security Studies, June 1998); Mike Worden, *Rise of the Fighter Generals: The Problem of Air Force Leadership, 1945–1982* (Maxwell AFB, AL: Air University Press, 1998).

3. In addition to the space-for-strategic-reconnaissance rationale advocated by RAND, other prominent rationales for space included the scientific imperative that found early expression in the International Geophysical Year (IGY) effort and the exploration imperative perhaps best captured by Wernher von Braun in a series of articles on future space stations published in *Collier's* magazine in the

continued on the next page

but the Eisenhower administration had secretly determined that its primary rationale for going to space was to attempt to open up the closed Soviet state via secret reconnaissance satellites. The RAND Corporation, a think tank sponsored by Army Air Force Commander General Henry H. "Hap" Arnold as a joint project with the Douglas Aircraft Company, was the first to study these issues systematically. RAND's very first report, "Preliminary Design of an Experimental World-Circling Spaceship," was delivered to the Army Air Force in April 1946 and not only detailed the technical design for and the physics involved in launching such a spaceship (the word satellite had not yet come into common usage), but also identified possible military missions for satellites, including communications, attack assessment, navigation, weather reconnaissance, and strategic reconnaissance.[4]

In October 1950, Paul Kecskemeti at RAND produced another comprehensive report on space that Walter A. McDougall believes should "be considered the birth certificate of American space policy."[5] This report highlighted the psychological impact the first satellite would likely have on the public and raised the issue of how the Soviet Union might respond to overflight of their territory and space-based reconnaissance. It even suggested that one way to test the issue of freedom of space would be first to launch an experimental U.S. satellite in an equatorial orbit that would not cross Soviet territory before attempting any satellite reconnaissance overhead the Soviet Union.

The Technological Capabilities Panel and NSC-5520

In March 1954, President Dwight Eisenhower commissioned a secret study and named Dr. James R. Killian, President of the Massachusetts Institute of Technology, as chairman of this Technological Capabilities Panel (TCP). With a thermonuclear standoff looming between the United States and the Soviet Union, Eisenhower wanted the best minds in the country to examine how technology might help to prevent another Pearl Harbor. The TCP report was delivered to the National Security Council (NSC) in February 1955. The report stands out as one of the most important and influential examinations of U.S. national security ever undertaken; it formed the foundation for U.S. national security planning for at least the next two years, made remarkably prescient

---

continued from the previous page

early 1950s. Several of these articles are reprinted in John M. Logsdon, ed., *Exploring the Unknown*, vol. 1, *Organizing for Exploration* (Washington, DC: NASA SP-4407, 1995), pp. 176–200.

4. Merton E. Davies and William R. Harris, *RAND's Role in the Evolution of Balloon and Satellite Observation Systems and Related Space Technology* (Santa Monica: RAND Corporation, 1988), pp. 6–9. Portions of RAND's first report are reprinted in Logsdon, *Exploring the Unknown*, vol. 1, pp. 236–244.

5. Walter A. McDougall, *. . . The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), p. 108.

predictions about the evolution of the superpowers' strategic nuclear arsenals, and called for crash programs to develop early-warning radars and ballistic missiles, as well as to improve the survivability of Strategic Air Command assets in the face of potential nuclear attack.[6]

The TCP also called for a vigorous program to improve U.S. technological intelligence collection capabilities. Killian and Edwin H. "Din" Land, founder of the Polaroid Corporation and chairman of the intelligence subcommittee of the TCP, were briefed on a wide range of potential collection methods and systems, including satellites, but became most enthused about attempting high-altitude reconnaissance overflights of the Soviet Union via a jet-powered glider that was then on the drawing boards at Clarence "Kelly" Johnson's Lockheed skunk works in Burbank, California. They recommended production of this new aircraft during a series of briefings that culminated in an Oval Office meeting on 24 November 1954, attended by the President, Secretaries of State and Defense, as well as top DOD and Central Intelligence Agency (CIA) officials.[7] The initial programs and structure for a national strategic reconnaissance program were discussed at this meeting; the President verbally authorized the CIA to begin development of the CL-282 (U-2) aircraft program with Air Force support.[8]

---

6. For the text of the TCP report, see John P. Glennon, ed., *Foreign Relations of the United States, 1955–1957*, vol. 19, *National Security Policy* (Washington: Department of State, 1990), pp. 42–55. James R. Killian, Jr., provides details on the workings of the TCP in *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology* (Cambridge: MIT Press, 1977), pp. 67–93. On the relationship between the TCP report and subsequent U.S. nuclear strategy, see Lawrence Freedman, *The Evolution of Nuclear Strategy* (New York: St. Martins Press, 1983), pp. 76–90.

7. Stephen M. Rothstein, *Dead on Arrival? The Development of the Aerospace Concept, 1944–58* (Maxwell AFB, AL: Air University Press, November 2000), p. 43; Clarence E. Smith, "CIA's Analysis of Soviet Science and Technology," in *Watching the Bear: Essays on CIA's Analysis of the Soviet Union*, ed. Gerald K. Haines and Robert E. Leggett (Langley, VA: Center for the Study of Intelligence, 2003); Gregory W. Pedlow and Donald E. Welzenbach, *The CIA and the U-2 Program, 1954–1974* (Langley, VA: Center for the Study of Intelligence, 1998). Land wrote a 5 November 1954 letter to CIA Director Allen W. Dulles outlining "A Unique Opportunity for Comprehensive Intelligence" via a specialized high-altitude aircraft; the letter is available electronically from the National Security Archive at *http://www2.gwu.edu/~nsarchiv/NSAEBB/NSAEBB74/U2-03.pdf*.

8. It is not clear from unclassified sources how much RAND reports or the Air Force's nascent WS-117L reconnaissance satellite system was discussed during these meetings. Satellite reconnaissance was strongly advocated by a series of RAND reports during the early 1950s (particularly the 1954 "Project Feed Back Report"; see Logsdon, *Exploring the Unknown*, vol. 1, pp. 269–274). In late 1953, the Air Research and Development Command (ARDC) had published a management "Satellite Component Study" and designated it Weapons System (WS) 117L. On 1 July 1954, the Western Development Division (WDD) of ARDC was established in Inglewood, CA, under the command of Colonel Bernard Schriever (who had participated in Project Feed Back), primarily to speed development of ballistic missiles. WDD formally initiated a program to develop reconnaissance satellites in Weapons System Requirements Number 5 (WS-117L), "System Requirement for an Advanced Reconnaissance System," secretly issued on 27 November 1954. According to Spires, "Focused on Project Aquatone,

continued on the next page

Following the start of these new technical intelligence collection initiatives, in early 1955 the National Academy of Sciences proposal for DOD to support the launch of a scientific satellite for research during the July 1957–December 1958 International Geophysical Year (IGY) landed on the desk of Donald Quarles, Assistant Secretary of Defense for Research and Development. Quarles used this opportunity to tie together various strands of the administration's embryonic policies on satellites, intelligence collection, and ballistic missiles by drafting a space policy for review by the National Security Council. His draft formed the basis for NSC-5520, the most important space policy of the Eisenhower administration. Portions of this document remain classified almost 50 years after it was written, but the basic themes are quite clear: the Space Age would soon open; the TCP "recommended that intelligence applications warrant an immediate program leading to a very small satellite in orbit around the earth" and a reexamination "of the principles or practices of international law with regard to 'Freedom of Space'"; DOD should provide support for launching the IGY satellite so long as such support would not delay or otherwise impede DOD programs; and all U.S. space efforts should be arranged to emphasize peaceful purposes and freedom of space.[9] NRO historian Cargill Hall succinctly summarized how Eisenhower's space policy was put into practice: "The IGY scientific satellite program was clearly identified as a stalking horse to establish the precedent of overflight in space for the eventual operation of military reconnaissance satellites."[10] The final piece of the policy, satellite, and booster puzzle fell into place when Quarles established an advisory committee to decide

---

continued from the previous page
the U-2 project that promised immediate results, the military satellite program received little interest or support from Killian and his experts. At that time, he considered the Air Force's reconnaissance satellite a 'peripheral project.' This attitude from one so influential helps explain the less than enthusiastic administration support of the Air Force's Advanced Reconnaissance Satellite in the two years preceding *Sputnik*. Despite the growing need for strategic intelligence and awareness that the U-2 represented a temporary solution, Killian declined to actively support the military satellite until after the launch of the first *Sputnik*. He believed an American scientific satellite had to precede the launch of a military vehicle to provide the overflight precedent for military satellites to operate with minimum international criticism" (David N. Spires, *Beyond Horizons: A Half Century of Air Force Space Leadership* [Colorado Springs: Air Force Space Command, 1998], p. 39). See Robert L. Perry, *Origins of the USAF Space Program, 1945–1956* (Los Angeles: Space Systems Division, 1961), p. viii, microfiche document 00313 in *U.S. Military Uses of Space 1945–1991: Index and Guide* (Washington, DC: The National Security Archive, and Alexandria, VA: Chadwyck-Healey, Inc., 1991); Spires, *Beyond Horizons*.

9. NSC-5520 was approved at the NSC meeting on 26 May 1955, and Eisenhower signed it the following day. Quotations are from the declassified portions reprinted in Dwayne A. Day, "Invitation to Struggle: The History of Civil-Military Relations in Space," in *Exploring the Unknown*, ed. John M. Logsdon, vol. 2, *External Relationships* (Washington, DC: NASA SP-4407, 1996), p. 241.

10. R. Cargill Hall, "Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in *Exploring the Unknown*, ed. Logsdon, vol. 1, p. 222.

which military booster should be used, and it recommended the Navy's Viking (Vanguard) booster rather than the Army or Air Force proposals.[11]

This most important but secret process to legitimize overflight spelled out by NSC-5520 was not at all clear at the time, even to many of the senior participants in the development of early U.S. space and missile programs. Indeed, it remained politically expedient to continue obscuring the origins and operation of space-based intelligence collection, America's first and arguably most important space program, for decades into the Space Age.[12] This subtext is, however, critical to understanding the nature of the relationships between NASA, the NRO, and the Air Force.

Responding to the Sputniks and Creating NASA

The Eisenhower administration carefully planned to use the opening of the Space Age to create a new legal regime that would legitimize the operation of reconnaissance satellites, but, despite repeated warnings, it did not prepare well for the psychological implications of this milestone. The worldwide public reaction to the Soviet successes with Sputniks I and II on 4 October and 3 November 1957 precipitated a crisis in confidence in Eisenhower's leadership that was seized upon by opponents of his New Look defense policies and shaped the remainder of his second term. In an attempt to limit the growing crisis, one of Eisenhower's first responses was to appoint Killian to a new position as science adviser to the President. A second major administration response was the establishment of the Advanced Research Projects Agency (ARPA) within DOD on 7 February 1958. ARPA was authorized to direct or perform virtually all United States space research and development efforts but was viewed by many as a stopgap measure and proved insufficient to derail the mounting pressure to create a comprehensive, independent, and civilian space agency.[13]

---

11. The Army Ballistic Missile Agency's Project Orbiter proposal was the most advanced of the proposals presented to the Stewart Committee. On 20 September 1956, a Jupiter-C rose to an altitude of 600 miles while traveling 3,000 miles downrange despite having an inert fourth stage (it was filled with sand) to preclude this vehicle from accidentally launching the first satellite and thereby circumventing the IGY stalking-horse strategy laid out in NSC-5520. See Major General John B. Medaris, U.S. Army (USA) (ret.), *Countdown for Decision* (New York: G. P. Putnam's Sons, 1960), pp. 119–20, 147.

12. The existence of the NRO was first officially acknowledged in September 1992. The importance and uses of United States overhead photoreconnaissance (IMINT), as well as the fact that the United States conducts overhead signals intelligence (SIGINT) and measurement and signature intelligence (MASINT) collection, were first acknowledged in the 19 September 1996 National Space Policy Fact Sheet.

13. Other major responses included authorization for the ABMA to prepare to launch a satellite on the modified V-2 booster known as the Jupiter-C or Juno (this system boosted Explorer I, America's first satellite, into orbit on 31 January 1958), as well as the congressional hearings on satellite and missile programs that were called by Majority Leader Lyndon Johnson and held between 25 November 1957 and 23 January 1958.

Killian was the most important actor in creating NASA as the centerpiece of the organizational structure America developed in response to the Sputniks shock, but he worked very closely with other key actors and organizations such as the President, Senator Lyndon B. Johnson (D-Texas), and the military services. By the end of 1957, the President's Science Advisory Committee (PSAC), under Killian, had decided that a scientifically oriented civil space program, rather than a military program, ought to be the nation's top space priority and that the new civilian space agency ought to be built out of and modeled after the National Advisory Committee for Aeronautics (NACA). This approach was the primary recommendation of the PSAC headed by Edward Purcell; Killian used the Purcell Committee findings to help persuade Eisenhower of the need for a civilian agency and sent proposed legislation to Congress on 2 April 1958.

Both houses held extensive hearings on the civilian space agency proposal during April and May; soon, however, they drifted into positions that differed from one another and from the administration. The most contentious issues revolved around three areas: the relative priority of civil and military space efforts, the appropriate relationship between civilian and military space organizations, and the organizational structure for creating national space policy. Office of the Secretary of Defense (OSD) witnesses included Deputy Secretary Quarles, ARPA Director Roy Johnson, and ARPA Chief Scientist Herbert York. They emphasized that DOD must retain the power to define and control military space programs. Service witnesses generally took the same positions they had over the creation of ARPA. The Navy opposed a strong civilian agency and preferred an organization similar to NACA that would support but not shape military space efforts. The Air Force was confident of its position as the lead service for military space and supported a strong civilian agency as a means to undercut Navy and Army space efforts. By contrast, the Army opposed the creation of a civilian agency or the division of scientific and military space missions; the Army also urged if a civilian space agency were created that it, rather than DOD or the Air Force, should control the national space effort.[14]

Compromises were ironed out following a meeting between Eisenhower and Senator Johnson on 7 July and during Conference Committee meetings later that month. The major compromises included a modified version of the House's Civilian-Military Liaison Committee (CMLC), creation of the National Aeronautics and Space Council (NASC) at the White House, and carefully brokered language in Section 102(b) that was designed to delineate between NASA and DOD space missions. The latter issue was perhaps the most controversial aspect of the entire process. The final language called for NASA to exercise control over all U.S. space activities

14. Enid Curtis Bok Schoettle, "The Establishment of NASA," in *Knowledge and Power: Essays on Science and Government*, ed. Sanford A. Lakoff (New York: Free Press, 1966), pp. 162–270.

> except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the U.S. (including Research and Development necessary to make effective provision for the defense of the U.S.) shall be the responsibility of and shall be directed by the DOD.[15]

Eisenhower signed the National Aeronautics and Space Act into law on 29 July, and NASA was created on 1 October 1958.

Frictions over manned spaceflight, budgets, and organizational structure between NACA and ARPA were evident before NASA was established. Both NACA and ARPA strongly desired to control manned spaceflight, and both organizations fought hard for this mission during a series of meetings with the Bureau of the Budget during the summer of 1958. Once again, Killian was an important player behind the scenes; he helped broker a compromise whereby NASA would design and build the capsules for manned spaceflight and DOD would concentrate on the boosters required for this mission.[16] Killian also pushed to reprogram $117 million from ARPA and the Air Force to NASA, helped ARPA retain $108 million for space programs outside of the WS-117L (see note 8), and steadfastly refused to entertain any suggestions to change the organization or reduce the $186-million budget for the WS-117L.[17] Organizational changes were also looming. The Army's Jet Propulsion Laboratory wished to transition immediately to NASA, and the Army was close to granting this request, but it wanted to use the transfer of JPL as a bargaining chip in its efforts to retain its space crown jewel, the von Braun rocket team at ABMA.

Completing the Organizational Structure

Following the creation of NASA, there were three major tracks of activity that shaped NASA-DOD relations during the remainder of Eisenhower's term and into John Kennedy's administration: moving ABMA into NASA, consolidating DOD space activities under the Air Force, and establishing the NRO. Each of these tracks helped establish the basic organizational structures and bureaucratic interests that endure today.

Army Secretary William Brucker and ABMA Commander Major General John Medaris understood very well how hard the Army had worked to capture and maintain the von Braun group as one of the key spoils of World War II and just how important von Braun's expertise would be to any major U.S.

15. Ibid., pp. 260–261.

16. Robert A. Divine, *The Sputnik Challenge* (New York: Oxford University Press, 1993), p. 150. Divine notes that Killian had quickly emerged as Eisenhower's "key post-*Sputnik* advisor."

17. Ibid., pp. 151–152.

space effort—they were not about to give up ABMA without a fight. They had strongly opposed creation of a powerful civilian space agency, and after NASA was established, they redoubled their efforts to retain control of ABMA. NASA had inherited NACA's infrastructure but initially lacked expertise in many space areas such as the development of large boosters. By contrast, ABMA contained arguably the world's best booster development team, but it lacked a specific military rationale for developing large boosters.[18] In October 1958, T. Keith Glennan, NASA's first Administrator, and Deputy Secretary Quarles worked out a deal to resolve this anomalous situation by transferring JPL and ABMA to NASA. Brucker and Medaris successfully blocked transfer of ABMA at this time. But in December, the NASC brokered a second compromise that moved JPL to NASA and left the von Braun team under ABMA while directing that their work on Saturn would be under contract to NASA.

Significant military space organizational restructuring was also under way within DOD. Following creation of NASA and pressure on ABMA, the Navy and the Army, in particular, became increasingly concerned with retaining their military space capabilities, shoring up ARPA, and formulating the proper bureaucratic structure for military space. The Air Force, by contrast, was growing increasingly confident of its inside track for gaining control over military space missions, supported a strong NASA, and continued to oppose ARPA's direction of military space efforts. Another key player that entered the mix at this time was Herbert York, the first Director of Defense Research and Engineering (DDR&E), a position created by the 1958 Defense Reorganization Act.

Debates over DOD's space organizational structure became increasingly heated during 1959 and came to a head in September. In April, Chief of Naval Operations Admiral Arleigh Burke highlighted the indivisibility of space and proposed to the Joint Chiefs of Staff (JCS) creation of a unified (multiservice) command for space. Burke's proposal was supported by the Army but was strongly opposed by the Air Force. Arguing that space systems represented a better way of performing existing missions, the Air Force advocated treating space systems on a functional basis under ARPA or, preferably, under the Air Force. DDR&E York weighed in on this debate and sided strongly with the Air Force, largely because he was eager to consolidate military space efforts under the Air Force as a way to rein in what he considered to be overreaching space proposals on the part of all the services. A memorandum

18. ABMA had been tasked by ARPA to study and design a 1.5-million-pound-thrust booster that came to be known as the Saturn B. The Saturn B was, in turn, a primary driver behind the ABMA Project Horizon proposal to use 149 Saturn launches to build a 12-person lunar outpost by 1966. See John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge: MIT Press, 1970), pp. 51–52.

from Secretary Neil McElroy to JCS Chairman General Nathan Twining on 18 September attempted to resolve these disputes and represented a significant bureaucratic victory for the Air Force. McElroy assigned responsibility for most satellite systems, payload integration, and "the development, production, and launching of space boosters" to the Air Force.[19] The memo also found that "establishment of a joint military organization with control over operational space systems does not appear desirable at this time."[20]

For the remainder of the Eisenhower administration and the beginning of the Kennedy administration, the space prospects of the Army continued to decline while those of the Air Force usually continued to rise. Following the transfer of the Redstone program in December 1958 and the Saturn program in November 1959, between March and July 1960 the Army moved the von Braun team and 6,400 other ABMA personnel under NASA control.[21] Eisenhower presided over the 8 September 1960 ceremony in Huntsville, Alabama, that dedicated the Marshall Space Flight Center and officially moved the Army out of the space business. It took decades for the Army to recover from this loss and regain its enthusiasm towards space, but today the Army is the largest user of military space data among the services, and it is eagerly considering a range of significant future enhancements such as Global Positioning System (GPS) III satellites and Blue Force Tracking.

Despite Air Force support for NASA's creation, NASA's role in absorbing the Air Force's most serious competition for developing military space systems, and generally good early relations between America's two largest space organizations, NASA–Air Force relations hit a snag after an internal letter from Air Force Chief of Staff General Thomas White to his staff was leaked to Congressman Overton Brooks (D-Louisiana), Chairman of the House Committee on Science and Astronautics. The bulk of White's 14 April 1960 letter urged the Air Force "to cooperate to the maximum extent with NASA, to include the furnishing of key personnel even at the expense of some Air Force dilution of technical talent."[22] The opening two sentences of White's letter, however, raised questions about the strength and longevity of Air Force support for NASA independence:

19. Spires, *Beyond Horizons*, p. 77. ARPA returned responsibility for the WS-117L to the Air Force. By this time, the program consisted of three separate developmental satellite systems: Corona, a recoverable film photoreconnaissance system; Samos, an electro-optical system designed to downlink imagery electronically; and Midas, an infrared satellite sensor system designed to detect ballistic missile launches. The Navy acquired the Transit satellite navigation systems, and the Army gained responsibility for Notus communications satellites. This approach overturned ARPA's monopoly on control over military satellite systems.

20. Ibid.

21. Day, "Invitation to Struggle," p. 253.

22. Ibid., p. 256.

President Dwight D. Eisenhower and Mrs. George C. Marshall unveil the bronze bust of General George C. Marshall during the dedication ceremony of the George C. Marshall Space Flight Center (MSFC) in Huntsville, Alabama, on 8 September 1960. On 21 October 1959, President Eisenhower directed the transfer of personnel from the Redstone Arsenal's Army Ballistic Missile Agency Development Operations Division to NASA. The complex of the new NASA Center was formed within the boundaries of Redstone Arsenal in Huntsville. MSFC began its operations on 1 July 1960 after the transfer ceremony, with Dr. Wernher von Braun as Center Director. *(NASA MSFC photo no. 9131490)*

> I am convinced that one of the major long term elements of the Air Force future lies in space. It is also obvious that NASA will play a large part in the national effort in this direction and, moreover, inevitably will be closely associated, if not eventually combined with the military.[23]

In March 1961, Brooks held hearings to discuss White's letter, the proper balance between military and civil space, and the general direction of U.S. space efforts. Brooks sought and even received clarification from President Kennedy. On 23 March, Kennedy wrote a letter to Brooks that emphasized several key points:

23. Ibid.

> It is not now, nor has it ever been, my intention to subordinate the activities in space of the National Aeronautics and Space Administration to those of the Department of Defense. I believe, as you do, that there are legitimate missions in space for which the military services should assume responsibility, but that there are major missions, such as the scientific unmanned and manned exploration of space and the application of space technologies to the conduct of peaceful activities, which should be carried forward by our civilian space agency.[24]

Kennedy's letter helped to delineate space missions between NASA and the Air Force and indicated Kennedy's growing emphasis on civil missions, an emphasis that would grow significantly stronger after Yuri Gagarin's orbital flight some three weeks later.

During the same month as the Brooks hearings, Air Force control over military space programs was solidified when Secretary Robert McNamara issued Defense Directive 5160.32, "Development of Space Systems." This directive built on Secretary McElroy's September 1959 memo and the January 1961 recommendations of incoming science adviser Jerome Wiesner. It gave the Air Force operational control over almost every military space program from research and development through launch and operations and stopped just short of naming the Air Force as DOD's executive agent for space. This was, of course, a welcome development for the Air Force, but McNamara's motivation, like York's before him, was to consolidate and prune rather than to encourage Air Force leadership in developing more robust military space activities.

The creation of NRO was the final major organizational response to the opening of the Space Age and was, like the IGY stalking-horse strategy in NSC-5520, an official state secret hidden from the public and even many of the leaders of U.S. civil and military space efforts. Following Sputnik, in January 1958 the NSC granted highest national priority to development of an operational reconnaissance satellite, but Eisenhower had doubts about Air Force management of the WS-117L program and was particularly troubled by press leaks about the program. Decisions made at meetings on 6–7 February 1958 between the President, Killian, Land, Director of Central Intelligence Allen Dulles, Secretary of Defense Neil McElroy, and Eisenhower's staff secretary, Colonel Andrew Goodpaster, created ARPA and publicly gave this new agency all open military space programs. In secret, these decisions also gave ARPA direction over the highest priority WS-117L and moved control of the Corona recoverable film photoreconnaissance system from the Air

24. Logsdon, *Exploring the Unknown*, vol. 2, p. 317.

Force to the CIA in an organizational structure that initially mirrored that of the U-2.[25]

U.S. efforts to develop operational spysat systems faced very daunting technological challenges during the late 1950s and early 1960s. Corona was the most mature technology, yet between February 1959 and June 1960, it still suffered a string of 12 consecutive failures of various types that prevented recovery of film imagery from space before achieving its first success in August 1960. These problems with Corona, along with even more serious difficulties with Samos and Midas, prompted Eisenhower, in May 1960, to direct his new science adviser, George Kistiakowsky, to put together a committee to recommend changes to improve these programs. Kistiakowsky and Defense Secretary Thomas Gates decided on the structure and charter of what became known as the Samos Panel and selected members including Under Secretary of the Air Force Joseph Charyk, Deputy DDR&E John Rubel, Killian, Land, York, and Purcell. The Samos Panel reported its recommendations at an NSC meeting on 24 August. Eisenhower and the NSC strongly supported the primary recommendation, immediate creation of an organization to provide a direct chain of command from the Secretary of the Air Force to the officers in charge of each spysat project; this decision was the genesis of the NRO.[26] It represented another vote of no confidence in the Air Force to manage spysat programs through military channels, moved this highest priority space mission and its products out of the military chain of command, and completed America's three-legged organizational structure for space.

In addition to the organizational changes discussed above, beginning in 1961 there was a major change in the way information was released about U.S. military space programs that had a significant effect both on contemporary analyses and the historiography of space. A security clampdown was slowly implemented, first on spy satellite programs and then on all military space efforts. The Samos 2 launch on 31 January 1961 was the first to be affected by the Kennedy administration's new publicity guidelines. Assistant Secretary of Defense for Public Affairs Arthur Sylvester and NRO Director Charyk worked out a very terse statement provided to the press following this launch

25. R. Cargill Hall, "Clandestine Victory: Dwight D. Eisenhower and Overhead Reconnaissance in the Cold War" (paper presented at the "Eisenhower and National Security for the 21st Century Symposium," Industrial College of the Armed Forces, Washington, DC, 26–28 January 2005); Day, "Invitation to Struggle," p. 250; Kenneth E. Greer, "Corona," in *Corona: America's First Satellite Program*, ed. Kevin C. Ruffner (Langley, VA: Center for the Study of Intelligence, 1995).

26. George Kistiakowsky, *A Scientist at the White House: The Private Diary of President Eisenhower's Special Assistant for Science and Technology* (Cambridge: Harvard University Press, 1976); Hall, "Clandestine Victory"; Gerald M. Steinberg, *Satellite Reconnaissance: The Role of Informal Bargaining* (New York: Praeger Publishers, 1983); Jeffrey T. Richelson, *America's Secret Eyes in Space: The U.S. Keyhole Spy Satellite Program* (New York: Harper & Row, 1990).

that contrasted significantly with the large prelaunch publicity packages which had been given out previously.[27] The remainder of 1961 saw a gradual tightening of the security classifications with less and less information provided with each successive launch.[28]

The Air Force chafed at these restrictions, and many officers, including General Schriever, continued publicly to press the case for an increased military space program. This ongoing public discussion of military space programs by the Air Force greatly irritated President Kennedy, and on more than one occasion, he called Sylvester directly, demanding to know why he had "let those bastards talk."[29] Following these calls, Sylvester's office greatly intensified the screening process required for all public releases on space. As a result of this widespread clampdown, planned speeches by Air Force general officers were very carefully screened by civilians in Sylvester's office for any references to the Samos program, and the winter–spring 1960–1961 *Air University Quarterly Review* issue devoted to "Aerospace Force in the Sixties" was heavily censored, including the removal of an article entitled "Strategic Reconnaissance" in its entirety.[30]

The final step in this security-intensification process was the classified DOD directive issued on 23 March 1962 known as the "blackout" directive. According to Stares, this directive

> prohibited advance announcement and press coverage of *all* military space launchings at Cape Canaveral and Vandenberg AFB. It also forbade the use of the names of such space projects as Discoverer, MIDAS and SAMOS. Military payloads on space vehicles would no longer be identified, while the programme names would be replaced by numbers.[31]

While this directive may have made it somewhat more difficult for the Soviets to distinguish between different types of U.S. military space programs and launches, it certainly made it much more difficult for the Air Force to sell its preferred space program to the public or Congress and helped to establish and perpetuate a wide divergence between public knowledge and perceptions of the NASA and DOD space programs.

---

27. Paul B. Stares, *The Militarization of Space: U.S. Policy, 1945–1984* (Ithaca: Cornell University Press, 1985), p. 64. Sylvester and Charyk were mindful of the volume of information provided in the past and deliberately opted for a slow blackout process in the hopes that this would arouse less attention than an abrupt blackout.

28. Richelson, *Secret Eyes*, p. 53. By the time of the Samos 5 launch on 22 December 1961, DOD officials would no longer confirm that the Samos program even existed.

29. Stares, *Militarization of Space*, p. 64.

30. Steinberg, *Satellite Reconnaissance*, p. 43.

31. Stares, *Militarization of Space*, p. 65, emphasis in original.

WRESTLING WITH THE RATIONALE FOR HUMAN SPACEFLIGHT IN THE EARLY SPACE PROGRAM

With the organizational structure for space completed, the majority of issues concerning the relationships and cooperation between NASA, the Air Force, and the NRO revolved around the rationale for human spaceflight, the organizations empowered to perform these missions, and developing and operating space launch vehicles. These issues were, of course, also instrumental in initially shaping and continuing to mold America's space bureaucratic structure.

Jockeying for Human Spaceflight Missions

The period from the opening of the Space Age until completion of NASA's Apollo Moon race was a time of both cooperation and intense competition between NASA and the Air Force. Both organizations were very interested in and believed they would be directed to develop major human spaceflight programs; their intricate dance fundamentally shaped these programs. The Air Force had emerged as the most powerful military space actor, advanced a variety of rationales for manned military spaceflight, and strongly believed—especially at the beginning of the Kennedy administration—that it would be given approval for a major manned spaceflight program. NASA, meanwhile, drew heavily on Army and Air Force expertise to develop its spaceflight programs and struggled to transition from science to prestige as the most important rationale for its manned spaceflight programs. During the 1960s, the Air Force was repeatedly rebuffed in its attempts to gain a foothold in military manned space missions; following the failure of Dyna-Soar, Blue Gemini, and the Manned Orbiting Laboratory (MOL), the Air Force was sufficiently chastened that it remains highly skeptical of manned military missions.

The Air Force had displayed a significant amount of interest in military manned spaceflight well before Sputnik, but, like almost all other space activities, this interest was energized following the Soviet triumph. The Air Force's earliest support was for the dynamic soaring (Dyna-Soar) concept for skipping off the Earth's atmosphere to extend the range of a spaceplane that might be used for a variety of missions including strategic bombing, reconnaissance, and antisatellite attacks.[32] By 1955, the Bell Aircraft Company had received

---

32. The idea of an antipodal bomber that would skip off Earth's atmosphere to achieve intercontinental range was developed by an Austrian, Dr. Eugen Sänger, and was considered in 1943 by von Braun and General Walter Dornberger at Peenemünde. Dornberger worked for Bell Aircraft after the war and was a tireless advocate for Dyna-Soar. The idea of flying to and from space held special appeal to the test pilots who derided the capsule approach to manned spaceflight as "Spam in a can." See Tom Wolfe, *The Right Stuff* (New York: Bantam Press, 1980). The definitive work on Dyna-Soar is Roy F. Houchin, *US Hypersonic Research and Development, 1944–1963: The Rise and Fall of Dyna-Soar* (London: Frank Cass, 2005).

over $1 million in Air Force funding and had raised an additional $2.3 million from six other aerospace firms willing to ante up company funds to support the prospect of a major Air Force manned military space mission.[33]

Following Sputnik, Air Force leaders were among the first to adopt a space-race attitude toward manned spaceflight and supported using either spaceplanes or capsules to achieve rapid results. In a 31 January 1958 letter from Deputy Chief of Staff for Research and Development Lieutenant General Donald Putt to the Air Research and Development Command, Putt advocated rapid development of manned spaceflight and indicated it was "vital to the prestige of the nation that such a feat be accomplished at the earliest technically practicable date—if at all possible before the Russians."[34] Recognizing that congressional deliberations on creating a civilian space agency were under way, the Air Force mounted a full court press to gain approval of its Manned Military Space System Development Plan (MISS) before the civilian agency was established.[35] The MISS plan received support from the highest levels of the Air Force and throughout many DOD offices but was shot down, first by ARPA Director Johnson on 25 July and then by the President a few weeks later, when he formally assigned the role of human spaceflight to NASA.[36]

The Rise and Fall of Dyna-Soar

After its failure to advance its MISS plans and Eisenhower's decision to make NASA primarily responsible for manned spaceflight, the Air Force refocused on the Dyna-Soar program, and it became the service's top space priority. The official start of the program came in November 1957, when Air Research and Development Command issued System Development Directive 464.[37] In May 1958, the Air Force and NACA signed a Memorandum of Understanding (MOU) indicating that Dyna-Soar would be a joint Air Force–NACA project managed and funded along the lines of the X-15 effort.[38] The program took more definite shape during 1959 and 1960, when the Air Force laid out a four-step development program that was designed to achieve full operational capability by 1966. The zenith for the program came early in the Kennedy administration, when the plans were finalized for a small, single-

33. McDougall, *Heavens and Earth*, p. 339.

34. "Early AF MIS Activity," microfiche document 00446 in *U.S. Military Uses of Space*.

35. Ibid. The MISS plan had four phases. The first, "Man-In-Space-Soonest," called for the first orbital flight by April 1960, and the last, "Manned Lunar Landing and Return," was to be accomplished by December 1965. The entire program was projected to cost only $1.5 billion.

36. Day, "Invitation to Struggle," p. 252.

37. "Review and Summary of X-20 Military Application Studies," microfiche document 00450 in *U.S. Military Uses of Space*.

38. "Memorandum of Understanding," document II-7 in *Exploring the Unknown*, ed. Logsdon, vol. 2, pp. 284–285.

seat, delta-winged space glider (designated as the X-20 in 1962) that would be launched atop a Titan III and land like an airplane.

Soon, however, the X-20 ran afoul of McNamara's systems analysis approach and his fears of provoking an action-reaction arms race in space. After McNamara refused to accelerate the program, even after receiving an unrequested extra $85.8 million from the House Appropriations Committee for fiscal year (FY) 1962, funding was cut to only $130 million for FY 1963 and 1964, and the first scheduled flight was slipped to 1966.[39] Next, McNamara's systems analysts "showed that a modified Gemini might perform military functions better and more cheaply than the X-20."[40] This finding prompted McNamara to attempt to gain a large role for the Air Force in Project Gemini, a move NASA Administrator James Webb successfully parried by citing the impact of such a restructuring on the nation's highest priority Apollo Program. Instead, on 23 January 1963, Webb and McNamara signed an agreement to allow DOD experiments on Gemini missions. During this time, the Air Force also proposed a plan to procure some of NASA's Gemini spacecraft under a program referred to as Blue Gemini.[41]

The creation of the DOD Gemini Experiments Program and studies on the military usefulness of a space station that would evolve into the Manned Orbiting Laboratory (MOL) program weakened the rationale for the X-20 and placed additional pressures on the troubled program.[42] In October 1963, the

39. McDougall, *Heavens and Earth*, p. 340; Stares, *Militarization of Space*, p. 130.

40. McDougall, *Heavens and Earth*, p. 340.

41. Stares, *Militarization of Space*, p. 79. DOD eliminated the Blue Gemini and Military Orbital Development System (MODS) programs from the Air Force budget in January 1963. The NASA-DOD experiment program was officially titled Program 631A, "DOD Gemini Experiments Program," and called for 18 experiments to be run on Gemini flights between October 1964 and April 1967 for a cost of $16 million. The experiments were programmed for areas such as satellite inspection, reconnaissance, satellite defense, and astronaut extravehicular activity. See Colonel Daniel D. McKee, "The Gemini Program," *Air University Review* 16 (May–June 1965): 6–15; Gerald T. Cantwell, "AF in Space, FY 64," pp. 31–36, microfiche document 00330 in *U.S. Military Uses of Space*.

42. NASA and DOD interactions during 1963 over the issue of future manned space stations greatly affected the X-20 and other Air Force man-in-space plans. In November 1962, the Air Force had completed a study on a limited military space station known as the MODS. Based upon the MODS concept, Webb and McNamara discussed the possibility of a joint station project, and on 27 April 1963, they agreed that neither organization would initiate station development without the approval of the other. McNamara pressed Webb for a commitment to a joint program, but Webb did not want to make any pledge that might sidetrack Apollo. Finally, after intervention by Vice President Johnson and the NASC, NASA and DOD agreed in September that, if possible, stations larger and more sophisticated than Gemini and Apollo would be encompassed in a single project. After DDR&E Harold Brown recommended to McNamara on 14 November that the X-20 be canceled and replaced by studies on what would become the MOL program, Brown next attempted, unsuccessfully, to coordinate a joint NASA-DOD station. NASA, wary that the fairly large and sophisticated station Brown favored might threaten its space turf, suggested that DOD pursue a smaller and less sophisticated space *laboratory* rather than a space station. DOD accepted at least the semantic importance of this distinction in initiating MOL studies for an independent military station. See Cantwell, "AF in Space, FY 64," pp. 16–23, microfiche document 00330 in *U.S. Military Uses of Space*.

PSAC compared the relative military utility of the Gemini, X-20, and MOL programs and judged that the X-20 held the least potential.[43] By this time, according to the editor of *Missiles and Rockets*, the X-20 had been "reviewed, revised, reoriented, restudied, and reorganized to a greater extent than any other Air Force program."[44] On 10 December 1963, Secretary McNamara publicly announced cancellation of the X-20 program and, at the same time, assigned primary responsibility for developing MOL to the Air Force.[45]

The MOL Program and the Demise of Military Spaceflight Dreams

Announced at the same time as the cancellation of the X-20, MOL quickly took the place of the X-20 and became the cornerstone of Air Force efforts to build a significant manned military presence in space. The Air Force put a great deal of energy, effort, and funding into MOL, and this project soon emerged as DOD's only manned military space program. Numerous technical and especially political problems beset the program, and MOL was repeatedly cut back and stretched out in the late 1960s. The Nixon administration officially canceled MOL on 10 June 1969. Having been repeatedly thwarted and left without any military man-in-space programs, for many years the Air Force became more resigned to the sanctuary school of thought on space and came to view plans and doctrines calling for the military to help control space or to exploit the high-ground potential of space as increasingly irrelevant.

The roots of the MOL program can be traced back at least to the "Global Surveillance System" proposed by Air Force Systems Command in November 1960.[46] As described above, the more direct inspiration for the MOL came from the MODS space station first proposed by the Air Force in June 1962, the 1963 DOD-NASA deliberations over the possibility of building a joint space station, and the cancellation of the X-20. In his Posture Statement for FY 1965, Secretary McNamara generally remained unconvinced of a specific need for military spaceflight but indicated that the time had come for U.S. military man-in-space efforts to "be more sharply focused on those areas which hold the greatest promise of military utility."[47] Accordingly, he had canceled the X-20, expanded the small-scale testing of the Mach 5-25 flight regime through the unmanned ASSET vehicle, initiated the DOD Gemini Experiments Program, and proposed MOL as a "much more important step" for investigating the possible military utility of man-in-space.[48]

---

43. McDougall, *Heavens and Earth*, p. 340.

44. Ibid., p. 341.

45. Between 1957 and 1963, the X-20 program consumed $400 million, or almost the same amount spent on Project Mercury.

46. Richelson, *Secret Eyes in Space*, p. 83.

47. House Committee on Armed Services, *Fiscal Years 1965–1969 Defense Program and Fiscal Year 1965 Defense Budget*, Hearing before the Committee on Armed Services, 88th Cong., 1st sess., 1964, p. 104.

48. Ibid., pp. 104–106, quotation from page 106.

During 1964 and the first half of 1965, the MOL program was subjected to intense scrutiny by OSD and underwent several design and program application changes. By mid-1965, specific missions and station designs were firmed up. Most importantly, MOL applications added in 1965 were designed to turn MOL into a formidable reconnaissance platform with a large 90-inch telescope and huge signals intelligence (SIGINT) antennas to be assembled on orbit alongside the station.[49] At a press conference on 25 August 1965, President Johnson formally

A 1960 concept image of the United States Air Force's proposed Manned Orbiting Laboratory (MOL), intended to test the military usefulness of having humans in orbit. The station's baseline configuration was that of a two-person Gemini B spacecraft that could be attached to a laboratory vehicle. The structure was planned to launch on a Titan IIIC rocket. The station would be used for a month, and the astronauts could return to the Gemini capsule for transport back to Earth. The first launch of the MOL was scheduled for 15 December 1969, but the program was canceled by Defense Secretary Melvin R. Laird in 1969. *(NASA HQ image no. 2B24070-Fig3)*

49. Stares, *Militarization of Space*, p. 98; Richelson, *Secret Eyes*, p. 85. Richelson indicates that the MOL telescope camera system would have had a resolution of approximately 9 inches and was designated as the KH-10. A depiction of construction of a 100-foot-diameter SIGINT antenna as a proposed MOL experiment is found in J. S. Butz, Jr., "MOL: The Technical Promise and Prospects," *Air Force/Space Digest* (October 1965): 44–45.

approved the development of MOL. The MOL design at this time called for a configuration approximately 54 feet long and 10 feet in diameter consisting of a Gemini B capsule attached to the 41-foot-long laboratory. The station was to be launched into polar orbit from Vandenberg AFB atop a Titan III-C booster.[50] The entire program was originally scheduled to include five manned flights of MOL beginning in 1968 at a cost of $1.5 billion.[51] The overall objectives of the program as approved in August 1965 were to

a) learn more about what man is able to do in space and how that ability can be used for military purposes,

b) develop technology and equipment which will help advance manned and unmanned space flight, and

c) experiment with this technology and equipment.[52]

The Air Force directed the MOL program, and the Navy was a minor partner in the effort.[53] The initial Air Force support for this program was unmistakable. In congressional testimony in early 1965, Deputy Chief of Staff for R&D Lieutenant General James Ferguson indicated that "MOL would provide the space testing and evaluation facility which we have long sought. We consider it to be the keystone of our future space program."[54] Earlier, Ferguson had simply identified the MOL as the Air Force's "most important space program."[55] More generally, Ferguson highlighted the need for MOL due to the Air Force belief "that man is the key to the future in space, and

50. Richelson, *Secret Eyes*, p. 85; Executive Office of the President, National Aeronautics and Space Council, *Report to Congress on Aeronautics and Space Activities, 1965* (Washington: GPO, 31 January 1966), pp. 49–50. MOL astronauts would transfer into the shirtsleeve environment of the laboratory via a hatch through the heatshield of the Gemini B capsule. MOL was designed for 30-day missions. At the completion of the mission, the astronauts would transfer back into the capsule and reenter; the station itself would eventually also reenter and burn up. The Titan III-C had originally been developed to launch the canceled X-20.

51. Executive Office of the President, *Aeronautics and Space Activities, 1965*, p. 50.

52. Ibid., p. 49. These three objectives in *Aeronautics and Space Activities, 1965* were considerably less detailed and ambitious than the six MOL objectives that Secretary McNamara and DDR&E Harold Brown had outlined in congressional testimony in early 1965. See, for example, the statement of Brown in U.S. Congress, Senate Committee on Armed Services and Subcommittee on Department of Defense of the Committee on Appropriations, *Military Procurement Authorizations, Fiscal Year 1966*, Hearings before the Committee on Armed Services and the Subcommittee on Department of Defense of the Committee on Appropriations, 89th Cong., 1st sess., 1965, pp. 413–414.

53. Richelson, *Secret Eyes*, pp. 91–92. The original MOL schedule called for Navy MOL astronauts to conduct extensive ocean surveillance and submarine tracking experiments during the fourth mission.

54. U.S. Congress, House Committee on Armed Services, *Hearings on Military Posture, Fiscal Year 1966*, Hearings before the Committee on Armed Services, 89th Cong., 1st sess., 1965, p. 1229.

55. Ibid., p. 1219.

that certain military tasks and systems will become feasible only through the discriminatory intelligence of man."[56]

Soon, however, MOL ran into substantial technical and very difficult political problems. An unmanned Gemini B capsule was successfully tested and recovered from space on 3 November 1966, but design changes and technical difficulties with the laboratory portion of MOL caused delays and weight increases in this portion of the hardware. Due to the greater weight of the laboratory, the booster configuration for MOL was redesigned for more thrust and designated as the Titan III-M.[57] More significantly, the political support for MOL began to erode from all quarters. The Johnson administration was attempting to deal with the effect of the buildup of the war in Vietnam on its Great Society programs and had little time or inclination to focus on MOL. The program also suffered from a lack of strong support within Congress, where space attention was focused on the growing Apollo costs and the upcoming Moon landing. Even within the Air Force, MOL began to face serious questioning as the war in Vietnam heated up and resources were required for this conflict and for more traditional development programs such as the C-5A transport aircraft. With declining political support, funding for MOL began to be cut well below the levels required to keep the program on its original schedule. By early 1969, the first manned MOL mission had been slipped to 1972, while the total projected cost of the program had risen from $1.5 billion to $3 billion.[58] Despite these difficulties, in February 1969 incoming Secretary of Defense Melvin Laird endorsed a comprehensive review of the program that "concluded that the continuance of the program is fully justified by the benefits to our defense posture anticipated from MOL; and that all MOL objectives established by the President in 1965 can now be met with a six- rather than a seven-launch program."[59] Additionally, the Nixon administration initially requested $525 million for MOL in FY 1970.[60]

The Nixon administration quickly and completely reversed its initial support for MOL. President Nixon was eager to limit the budget, and MOL soon emerged as "an ideal target for OMB."[61] The actual decision to terminate MOL was apparently made at a White House meeting of OMB representative Robert Mayo, National Security Advisor Henry Kissinger, and President Nixon.[62] As

56. Ibid., p. 1228.

57. Richelson, *Secret Eyes*, p. 90.

58. Ibid., pp. 101–102.

59. Quoted from prepared statement of Air Force Chief of Staff General John McConnell in U.S. Congress, Senate Committee on Armed Services, *Authorization for Military Procurement, Research and Development, Fiscal Year 1970*, Hearings before the Committee on Armed Services, 91st Cong., 1st sess., 1969, p. 956. This cutback meant that MOL would now include only four manned missions rather than the five originally planned.

60. Ibid., p. 957.

61. Quoted from an unnamed "senior Air Force officer" in Stares, *Militarization of Space*, p. 159.

62. Richelson, *Secret Eyes*, p. 102.

they made clear in subsequent congressional testimony, Secretary Laird and the JCS were not consulted prior to this decision.[63] The public announcement of the cancellation of the MOL program came on 10 June 1969. A total of $1.4 billion was spent on the MOL program, making it one of the most expensive military programs ever prematurely terminated as of that date.[64]

The cancellation of MOL must also be viewed within a broader context than just the budgetary concerns of the Nixon administration. Shortly after entering office, Nixon had established a Space Task Group (STG) comprised of Vice President Spiro Agnew, Acting NASA Administrator Thomas Paine, Secretary Laird, and science adviser Lee DuBridge.[65] Nixon tasked the STG to complete a comprehensive review of the future plans of the U.S. space program. The STG national-level review was supported by reports from working groups at the departmental level. The DOD working groups in support of the STG studied future military space plans and budgets and again raised the issue of the military utility of MOL in an era of constrained budgets. More specifically, a report for the STG prepared by Walter Morrow of MIT's Lincoln Laboratory "declared that no significant increase in space spending was necessary to meet DOD requirements and that an annual military space investment of about $2 billion would suffice through the 1970s."[66] In competition for scarce space program funds, MOL did not necessarily do well even in DOD-sponsored analyses.

The most significant factor in the demise of the program, however, was the growing belief that unmanned spy satellites could perform the primary mission of MOL as well as or better than MOL and at a lower cost. According to Richelson, the NRO and CIA had been leery of the idea of a manned reconnaissance system from the outset. They reasoned that a manned system might present more of a provocation to the Soviets, that the contributions of manned operators in space would not be all that significant when balanced against the costs and requirements of life-support systems, and that any accident involving MOL astronauts might set back the whole space-based intelligence-gathering process unacceptably.[67] Moreover, beginning in 1965, NRO had begun development of the United

63. Ibid.

64. Ibid.

65. Air Force Secretary Robert Seamans represented Secretary Laird at STG meetings. Seamans had previously been NASA's Associate Administrator.

66. Jacob Neufeld, "The Air Force in Space. 1969–1970," Secret History, Office of Air Force History, July 1972, p. 4, microfiche document 00338 in *Military Uses of Space*. The overall military input to the STG, "DOD Programs, Options, Recommendations," was largely shaped by the Air Force and outlined four primary military space objectives: "(1) information gathering; (2) deterrence; (3) limiting enemy damage to the nation; and (4) support of Allied forces." This report also grouped possible future space efforts into three categories: 1) improvements on existing and planned mainstream space systems, primarily for force enhancement; 2) systems responsive to "significant technological or engineering advances, changes in national policy, or the emergence of new threats" such as a deep space command post; and 3) "undefined" systems such as Earth illumination systems or weather-modification systems (ibid., pp. 2–4).

67. Richelson, *Secret Eyes*, p. 103.

States' fourth-generation photoreconnaissance satellite known as the KH-9 or "Big Bird"—a system originally planned to serve as a backup to MOL.[68] In the late 1960s, with MOL already in jeopardy, the NRO now argued that the projected capabilities of the KH-9 system would make the MOL unnecessary. It is not possible in open sources to trace the exact impact of this argument on the decision to cancel MOL, but it may have been the clincher, given the development paths of both programs and subsequent events. The first KH-9 was launched from Vandenberg AFB atop a Titan III-D on 15 June 1971.[69]

The saga of the demise of the MOL program served as another painful lesson to the Air Force and the military that their preferred military space doctrines and programs would not come to fruition. The loss of MOL hit the Air Force very hard because 1) it was the Air Force's only attempt to establish a major manned military space program during this period, 2) the Air Force had planned to use MOL as the basis to build a larger manned military space presence, and 3) the program had been specifically tailored primarily to support the space-as-sanctuary school but had still been rejected. After the Air Force's plan to use men in space to support the nation's highest priority military space mission was not approved, it was very unlikely that any other military man-in-space program would be approved. For a number of years after the cancellation of the MOL, the Air Force largely lost interest in high-ground and space-control doctrines and basically considered the development of a significant manned military space presence a lost cause. Stares summarizes the organizational impact of the loss of the X-20 and the MOL programs upon the Air Force during this period very well:

> With the cancellation of the Dynasoar and MOL, many believed in the Air Force that they had made their "pitch" and failed. This in turn reduced the incentives to try again and reinforced the bias towards the traditional mission of the Air Force, namely flying. As a result, the Air Force's space activities remained a poor relation to tactical and strategic airpower in its organizational hierarchy and inevitably in its funding priorities. This undoubtedly influenced the Air Force's negative attitude towards the various ASAT modernization proposals put forward by Air Defense Command and others in the early 1970s. The provision of satellite survivability measures also suffered because the Air Force was reluctant to propose initiatives that would require the use of its own budget to defend the space assets of other services and agencies.[70]

---

68. Ibid., p. 105; Stares, *Militarization of Space*, p. 160; William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Berkley Books, 1986), pp. 228–229.

69. "Launch Listing," in *U.S. Military Uses of Space*, p. 100. The Titan III-D launch vehicle for the KH-9 was very similar to the Titan III-M designed to launch the MOL.

70. Stares, *Militarization of Space*, p. 242.

DOD and the Development of the Space Shuttle

Interactions between NASA, the NRO, and the Air Force were among the most important inputs in structuring the development and operation of the Space Transportation System (STS) or Shuttle program. STS interactions deserve special attention because they were the most focused, longest running, and most intense interplay among these organizations and became the single most important factor in shaping their interrelationships. NASA's decision to pursue a large shuttle vehicle program to serve as the national launch vehicle was the Agency's primary post-Apollo space program goal. This decision necessitated that the Shuttle design be able to accommodate the most important potential users and satisfy the military in particular. Accordingly, DOD was instrumental in setting Shuttle payload and performance criteria. Even more importantly, when the STS ran into great political and budgetary problems during the Carter administration, DOD stepped in to help save the program—largely due to the Shuttle's projected capability to launch huge spy satellites. Thus, the rationale behind the STS development became increasingly militarized and related to spy satellites. Additionally, STS operations up to the *Challenger* disaster allowed the military to again entertain plans to develop a manned military presence in space.

The question of what the U.S. should focus on in space following its triumph in the Moon race was the overriding issue for U.S. space policy in the late 1960s and early 1970s. President Nixon created the Space Task Group (STG) in February 1969 to examine this issue. On 15 September, the STG presented Nixon with three options for post-Apollo U.S. civil space plans. Option one called for a manned mission to Mars by 1985 supported by a 50-man space station in orbit around Earth, a smaller space station in orbit around the Moon, a lunar base, a space shuttle to service the Earth space station, and a space tug to service the lunar stations. Option two consisted of all of the above except for the lunar projects and delayed the Mars landing until 1986. Option three included only the space station and the space shuttle, deferring the decision on a Mars mission but keeping it as a goal to be realized before the end of the century.[71] The report estimated that option one would cost approximately $10 billion annually, option two would run about $8 billion per year, and option three would be $5 billion annually.[72] Considering that NASA's budget had peaked at the height of the Moon race in 1965 at a little more than $5 billion and that political support for space spectaculars was rapidly eroding, the STG recommendations seemed fiscally irresponsible and politically naive.[73]

---

71. Colonel Cass Schichtle, USAF, *The National Space Program From the Fifties to the Eighties* (Washington: National Defense University Press, 1983), pp. 72–73; McDougall, *Heavens and Earth*, p. 421.

72. McDougall, *Heavens and Earth*, p. 421.

73. Schichtle, *National Space Program*, p. 69.

Meanwhile, the Air Force and NASA had begun coordinating with one another concerning the need for, design criteria, and performance capabilities of a shuttle vehicle. In March 1969, STG Chairman Agnew had directed that a joint DOD-NASA study on a shuttle system be completed to support the overall STG effort.[74] During the spring of 1969, Air Force Chief of Staff General John McConnell was very impressed with the military potential of a shuttle vehicle and even "proposed the Air Force assume responsibility for STS development."[75] Air Force Secretary Robert Seamans was also impressed with the potential of a shuttle but "he vetoed the proposal that the Air Force take charge of STS development, preferring to await additional study results."[76] In June, DOD and NASA submitted to the STG their coordinated report that strongly backed development of a shuttle.[77] By contrast, the Morrow report, which was also prepared for the STG, questioned the technical feasibility of a shuttle and specifically refuted the projected STS launch rates and cost estimates. The Morrow report recommended "the DOD postpone its participation in the system's development pending technical and economic analysis."[78]

DOD and the Air Force acknowledged some of the potential STS difficulties raised by the Morrow report but remained supportive of shuttle development. The military specifications for the shuttle at this time included a 50,000-pound payload capability for launches into a 100-nautical-mile (NM) due-east orbit, a payload compartment measuring 15 by 60 feet, and a cross-range maneuvering capability of 1,500 NM.[79] Some NASA shuttle designs did not meet all of these criteria, but NASA quickly recognized the political necessity for strong Air Force support in attempting to sell the shuttle within the administration and agreed specifically to include the Air Force in future STS design and policy decision-making.

---

74. Neufeld, "Air Force in Space. 1969–1970," p. 5, microfiche document 00338 in *U.S. Military Uses of Space*.

75. Ibid., p. 6.

76. Ibid.

77. Ibid., pp. 6–7. Specifically, "the report concluded that STS development (1) would require no significant 'breakthrough' in technology, (2) could achieve 'a major reduction in the recurring costs of space operations,' and (3) could meet the requirements of both agencies without 'major technical penalty, development risk, limitation on mission flexibility, or cost increase.'" Neufeld's interior quotations are from the report itself. The report recommended a $52-million allocation in FY 1970 for design studies. Moreover, the report also found that the STS could be operational by 1976 for $4–6 billion; projected a launch rate of 30 to 70 flights per year; and estimated that with 100 uses, the STS would lower launch costs per pound into low-Earth orbit to $50–100 and into geostationary transfer orbit to $500.

78. Ibid., p. 7. The Morrow report is also discussed in relation to the MOL in the MOL section above.

79. Ibid., p. 8. The Air Force's weight and volume requirements for the STS seemed to be driven by projected spysat designs, whereas the cross-range maneuverability requirement was apparently a general military requirement relating to safety, survivability, and flexibility considerations. Some critics within NASA and other analysts have charged that these requirements (especially the cross-range criteria) were arbitrarily set too high, caused very significant design changes, and later contributed to STS program delays. See, for example, the positions raised in John M. Logsdon, "The Decision to Develop the Space Shuttle," *Space Policy* 2 (May 1986): 103–119.

To formalize this arrangement, on 17 February 1970 the Air Force signed an agreement with NASA that established the joint USAF/NASA STS Committee.[80]

On the basis of the STG report and the recommendations from other space studies during this period, President Nixon moved to formalize U.S. post-Apollo space policy goals in March 1970.[81] Nixon only endorsed the development of a shuttle and left a space station or a Mars mission contingent upon the successful completion of a shuttle program. Of course, this was far less than NASA had hoped for, and the agency that had conquered the Moon was initially less than enthused about the prospect of building a nonglamorous space truck as its primary post-Apollo mission.[82] Soon, however, NASA came to realize that a space shuttle was the only major program that stood a chance of being approved at this time and the only possible way to preserve at least a part of NASA's integrity in the face of radical cuts in civil space programs and budgets.[83]

Faced with this situation, NASA continued its attempts to design a space shuttle during 1970 and 1971. In late 1970 and early 1971, acting Administrator George M. Low continued Paine's emphasis on the shuttle as a national vehicle by moving NASA from concept towards design of a larger and more capable shuttle. Thus, by 1971, NASA was hard at work on what has been described as a "Cadillac" shuttle system—very large, very capable, and completely reusable, but very expensive to develop.[84] These very capable designs proved to be too expensive, especially after the Office of Management and Budget (OMB) reiterated that NASA could expect no more than $6.5 billion to develop the shuttle.[85] Meanwhile, the Air

80. Neufeld, "Air Force in Space. 1969–1970," p. 9. Creation of this committee did not solve all of the Air Force–NASA differences over STS design issues. Powerful elements within NASA, such as Associate Administrator for Manned Spaceflight Dr. George E. Mueller, continued to press for a smaller STS design that would not meet all of the Air Force's criteria.

81. Two of the most important other studies on U.S. post-Apollo space goals that were also completed during this period but not mentioned above were 1) the overall NASA input into the STG, known as the Mueller report after its chairman, George Mueller, and 2) the PSAC report, headed by Lewis Branscomb. The Mueller report stressed a building-block approach for the next major civil space programs and emphasized the general utility of a space shuttle for all other projects. The Branscomb report urged that the U.S. place more emphasis on unmanned versus manned exploration and recommended robotic exploration of Mars. On these two reports and their impact, see Hans Mark, *The Space Station: A Personal Journey* (Durham, NC: Duke University Press, 1987), pp. 31–34.

82. NASA Administrator Thomas Paine resigned in September 1970 over this issue and over his general perceptions of a lack of support for NASA within the Nixon administration. See Joseph J. Trento, *Prescription for Disaster* (New York: Crown Publishers, 1987), pp. 84–99.

83. NASA's budget (in constant dollars) fell to only 36 percent of its 1965 peak by the time of its nadir in 1975. The speed of these reductions meant that NASA's budget often was reduced by more than $500 million, or more than 10 percent, in constant dollars each year. Moreover, the number of jobs in the civil space sector dropped from a peak of 420,000 in 1966 to only 190,000 by 1970 and continued down from that point. See Schichtle, *National Space Program*, p. 73; "NASA Budget History," *Aviation Week & Space Technology* (16 March 1992): 123.

84. Alex Roland, "Priorities in Space for the USA," *Space Policy* 3 (May 1987): 106. Roland is a former NASA historian.

85. Logsdon, "Decision to Develop the Space Shuttle," p. 107.

Force remained adamant on its payload and performance criteria and apparently even raised its maximum payload weight requirement to 65,000 pounds.[86] During the remainder of 1971, NASA came up with a revised shuttle design known as the Thrust-Assisted Orbiter Shuttle (TAOS) that seemed to meet these demanding development cost ceilings and performance criteria better.[87] After very intense scrutiny from the OMB during the fall of 1971, the TAOS design went forward to President Nixon for final approval.[88] Nixon privately decided to approve the full-scale TAOS at the Western White House at San Clemente over the 1971–72 New Year's weekend.[89] James Fletcher, the new NASA Administrator, went to the Western White House to brief the President and to be present when the decision to approve the STS was publicly announced on 5 January.

Other than setting the payload and performance design criteria discussed above, the Air Force was not very involved, financially or otherwise, in the STS program during most of its development period. In 1971, the Air Force agreed that it would not compete against the STS and would forgo the development of any new expendable launch vehicles (ELVs).[90] In April 1972, the Kennedy Space Center (KSC) and Vandenberg AFB were selected as Shuttle launch and landing sites, and the Air Force agreed to reconfigure the planned MOL launch complex at Vandenberg, known as space launch complex (SLC)-6, for STS launches into polar orbit.[91] Interestingly, former NASA Administrator Fletcher claimed in a later interview that the Air Force had verbally committed to him during STS development that they would buy the planned fifth and sixth orbiters.[92]

86. Ibid., pp. 108–110. Here, Logsdon discusses the Air Force's payload and performance criteria. He indicates that the most important Air Force weight requirement was for the capability to launch 40,000 pounds into polar orbit and that the 15-foot dimension of the cargo bay was a NASA requirement for possible future station construction rather than an Air Force criterion.

87. The TAOS design moved away from the original designs, which called for a vertically stacked booster-orbiter configuration staging in sequence, as in all previous spacecraft designs, to a horizontally stacked booster-orbiter design where the booster and orbiter engines could be used at the same time. This design also moved the large main fuel tank outside the booster and made this section expendable rather than reusable. The TAOS design lowered the overall size and weight of the vehicle by allowing the Space Shuttle Main Engines (SSMEs) to contribute to takeoff thrust, but it also greatly increased the technological challenges for designing the SSMEs and introduced the problem of asymmetrical thrust on takeoff. This and other design decisions at this time lowered the development costs for the STS but would also contribute significantly to the much higher than desired STS operations costs.

88. Logsdon describes the NASA-OMB exchanges in detail in "Decision to Develop the Space Shuttle," pp. 112–116.

89. Ibid., p. 118.

90. Ibid., p. 110.

91. Major General R. C. Henry and Major Aubrey B. Sloan, "The Space Shuttle and Vandenberg Air Force Base," *Air University Review* 27 (September–October 1976): 19–26. The Aeronautics and Astronautics Coordinating Board formally approved SLC-6 reconfiguration for STS launches in January 1975.

92. Trento, *Prescription for Disaster*, p. 128. I was unable to find any hard evidence of such a commitment. In the wake of the *Challenger* disaster, many varied theories were advanced to determine culpability for the woes of the STS program.

Throughout the remainder of the 1970s, the STS faced difficult technical and political challenges. Three major technical challenges were the most difficult: developing the computer software and interfaces for the orbiter's computer-controlled flight system, designing and especially attaching the ceramic tiles for the orbiter's heat-protection system, and designing and testing the Space Shuttle Main Engines (SSMEs). Politically, the STS faced even more difficult challenges at the outset of the Carter administration. Several powerful individuals and organizations such as Vice President Walter Mondale, the OMB, and the Office of Science and Technology Policy (OSTP) favored drastically cutting back the STS if not canceling the program outright.[93] In the summer of 1977, as the test vehicle *Enterprise* was about to begin STS approach and landing tests at Edwards AFB, President Carter asked newly appointed NASA Administrator Robert Frosch to evaluate comprehensively whether to continue with the STS program.[94] Thus, the stage was set for the most difficult challenge the STS would face during its development process.

At this point, DOD stepped in strongly to defend the STS as a program critical to national security and to play an important role in preserving this program. In July 1977, Dr. Hans Mark, who had been Director of NASA's Ames Research Center, became Under Secretary of the Air Force (and NRO Director). As an avid manned spaceflight enthusiast who believed the STS was an essential step towards a future manned space station and future exploration, Mark was instrumental in lining up DOD support for the STS in its time of peril. During November and December of 1977, OMB called a series of meetings on the future of the STS.[95] The OMB had urged that the STS program be converted into a three-orbiter test project and that only the KSC launch site be built.[96]

According to Mark, Secretary of Defense Harold Brown was persuasive in making the DOD's need for the STS clear at these meetings:

> [Brown] made the case that at least two launch sites (one on the east coast and the other on the west coast) would be required and that at least four Orbiters would be necessary to meet the requirements of national security. This last argument was based on the fact that the first two Orbiters to be built (OV-102, *Columbia*,

93. Mondale had helped to make a name for himself in the Senate both with his attacks on the "bloated" NASA budgets of the late 1960s and as a leader of congressional opposition to building the STS. In 1973, President Nixon had abolished the NASC and moved the science adviser's office out of the Executive Office of the President (EOP). In 1976, President Gerald Ford created OSTP within EOP. Carter's OSTP Director, Dr. Frank Press, saw government funding for all scientific efforts as a zero-sum game and was eager to address the deficiencies he perceived in basic scientific research funding by reducing quasi-scientific efforts such as manned spaceflight.

94. Trento, *Prescription for Disaster*, p. 149.

95. Mark, *Space Station*, pp. 71–73.

96. Ibid., p. 72.

> and OV-099, *Challenger*) would be somewhat heavier than the following vehicles and would therefore not be capable of carrying the very heaviest national security related payloads. It was therefore necessary to have at least two Orbiters capable of carrying the very heaviest payloads in order to have a backup in case one of these vehicles was lost. This argument carried the day and the decision was reached to build four Orbiters (OV-103, *Discovery*, and OV-104, *Atlantis*, in addition to the first two) and to continue with construction of the west coast launch site. (The west coast launch site was deemed necessary in order to conduct polar orbiting flights required for national security related missions.)[97]

Although Mark does not highlight another aspect of saving the STS, sometime during this period, perhaps at these OMB meetings, the decision was also taken to make the STS virtually the only launch vehicle for both NASA and DOD.

The outcome of these meetings marked a definite shift in the rationale for the STS program that again illustrates the overriding impact of spysats on all other types of space policy. NASA was publicly selling the STS program as a way to meet U.S. civil space policy goals and on cost-effectiveness grounds, but the rationale that saved it during the Carter administration was its ability to launch huge spy satellites. Moreover, with the pending debate over the ratification of the SALT II Treaty, spy satellites as national technical means of verification took on added significance. On 1 October 1978, President Carter marked the first official break with the blackout policy on spysats promulgated in 1962. In a speech at the KSC, Carter noted that "photoreconnaissance satellites have become an important stabilizing factor in world affairs in the monitoring of arms control agreements. They make an immediate contribution to the security of all nations. We shall continue to develop them."[98] Meanwhile, however, the NRO was ambivalent about the prospects of using the STS as its sole launch vehicle: on

97. Ibid.

98. Cited in Stares, *Militarization of Space*, p. 186. According to Richelson, *Secret Eyes*, pp. 140–143, various agencies within the administration debated during early September how far to go in declassifying spysats. The primary motivation behind the desire to loosen the security restrictions on spysats was publicly to provide administration officials with better evidence of U.S. ability to verify SALT II adequately. Those arguing for greater declassification included Secretary of State Cyrus Vance, Arms Control and Disarmament Agency Director Paul Warnke, Director of Central Intelligence Stansfield Turner, National Security Agency Director Bobby Inman, and NRO Director Mark. Secretary Brown, backed by the JCS and the Defense Intelligence Agency, strongly opposed widespread declassification. The most powerful argument raised by DOD (which apparently won the day) was that the release of one spysat photo would lead to a deluge of Freedom of Information Act (FOIA) requests and thereby tie up the manpower of the intelligence agencies in nonproductive activities. On 13 September, the Policy Review Committee (Space) voted for declassification, but only of the fact that the United States conducted photoreconnaissance from space—a "truly minimalist decision," in Richelson's opinion.

the one hand, it was already planning the large spysats that would take advantage of STS capabilities; but on the other hand, it did not want to lose control over its launch vehicles, feared the possible disruption of spysat launchings due to accidents with astronauts, and also chafed at the prospect of the increased media attention that NASA involvement would bring.

General Air Force attitudes towards STS were also ambivalent during this period. While STS was strongly supported by elements within the Space and Missiles Systems Organization and by Mark (who became Secretary of the Air Force in July 1979), other elements such as the Secretary of the Air Force Special Projects Office were less enthusiastic. Mark attempted to push STS and a general space emphasis on the Air Force.[99] These efforts, along with the military potential of the STS, certainly were important in helping to revive Air Force interest in space and in possible military man-in-space applications. At the same time, however, the Air Force was very much a junior partner on STS in terms of funding and effort. Moreover, the Air Force dragged its feet on refurbishing SLC-6 at Vandenberg for STS operations and in developing the Inertial Upper Stage (IUS) to be used for boosting payloads into higher energy orbits than possible with the STS.[100] In sum, then, although the STS program did reignite some Air Force interest in more ambitious space missions, the level of Air Force support for this program by the end of its development did not approach the level of enthusiasm the Air Force had displayed for the X-20 or MOL, and this ambivalent support undoubtedly reflected the fact that the Air Force did not control STS.

The Military, Space Transportation Policy, and STS Operations

The 1980s witnessed both the long-awaited arrival of STS operations and the wrenching reordering of U.S. space transportation policy following the *Challenger* disaster. DOD interactions with the STS program continued to be a very important factor in shaping this program, while DOD's stance on STS provides important insights into the military's space priorities and actual level of commitment to various space programs. Despite the great military potential of the STS and the considerable support for the STS within elements of the Air

---

99. Mark listed "the development of a doctrine and an organization that will permit greatly increased Air Force activities in space in order to take advantage of new technology to enhance communications, reconnaissance, and other vital Air Force functions" as one of the USAF's top priorities. Hans M. Mark, "USAF's Three Top Priorities," *Air Force Magazine* (September 1979), reprinted as appendix 3 in Mark, *Space Station*, pp. 235–236.

100. It is difficult to apportion blame for delays on the STS program; however, STS was originally scheduled to be launched from SLC-6 in December 1982 (after "more than forty launches will have taken place from KSC"!), and SLC-6 would barely have been ready for its rescheduled first launch in March 1986 had the *Challenger* disaster not derailed that plan. In practice, there were only 5 STS flights by December 1982 and a total of only 24 flights prior to the *Challenger* disaster. See Henry and Sloan, "Shuttle and Vandenberg," p. 25; Edgar Ulsamer, "Slick 6," *Air Force Magazine* (November 1985): 47–48.

Force and elsewhere in DOD, several significant points of friction remained between the Air Force, NRO, and NASA concerning STS operations and plans. Even prior to the *Challenger* disaster, the NRO had managed to gain formal approval to build a backup launcher, the Complementary ELV (CELV), for its most important payloads. Following the *Challenger* disaster, U.S. national space transportation policies were completely reordered under the Space Launch Recovery Plan, and the Air Force planned to move almost all DOD payloads onto ELVs. NASA-DOD interactions over STS during the 1980s led to the reversal of several major space transportation policies, abandonment of the original STS program goals, and the demise of yet another potential vehicle for significant military spaceflight.

DOD was instrumental in saving STS from cancellation at the outset of the Carter administration and was again a key player in defending STS late in the Carter administration when the program faced significant political opposition due to successive schedule slips and funding shortfalls requiring supplemental appropriations.[101] DOD support for the STS was critical in maintaining political support for STS within the administration and culminated in a 14 November 1979 White House meeting between the President and all key actors on this issue, where Carter firmly committed his administration to fully funding and rapidly completing STS.[102] DOD support for the national security mission of the STS was also a key factor in pushing the supplemental appropriations through Congress following hearings in March 1980.[103]

DOD exacted a price from NASA for its indispensable support: on 25 February 1980, NASA and DOD signed an extensive MOU on management and operation of the STS which was very favorable to DOD.[104] Specifically, the MOU indicated that "DOD will have priority in mission preparation and operations consistent with established national space policy."[105] Further, the

101. In 1979, NASA required supplemental appropriations totaling over $1 billion (1972 dollars) to keep the STS program on track. See Mark, *Space Station*, p. 93.

102. Mark, *Space Station*, pp. 101–103; Trento, *Prescription for Disaster*, p. 169.

103. Representative Edward Boland (D-Massachusetts) was instrumental in gaining approval for these supplemental appropriations as chairman of the NASA appropriations subcommittee. His support for STS stemmed from his position as Chairman of the House Permanent Select Committee on Intelligence, where he learned about the STS-spysat link in detail. See Mark, *Space Station*, p. 105; Trento, *Prescription for Disaster*, pp. 156–157.

104. "NASA/DOD Memorandum of Understanding on Management and Operation of the Space Transportation System," 25 February 1980, microfiche document 00561 in *U.S. Military Uses of Space*. This MOU replaced the 14 January 1977 NASA-DOD MOU on STS and provided the basis for several NASA-DOD subagreements.

105. Ibid., p. 3. The "established national space policy" referenced is presumably Presidential Directive (PD)-37 signed by President Carter on 11 May 1978 (unclassified version available at *http://www.au.af.mil/au/awc/awcgate/nsc-37.htm*). This DOD mission priority on the STS was often referred to as the right of DOD to "bump" other payloads from the STS manifest in favor of top-priority national security

continued on the next page

MOU established two categories of DOD STS missions: 1) national security missions conducted by NASA and 2) "Designated National Security Missions" controlled by the Air Force.[106] Overall, this MOU went a long way towards giving the Air Force the type of operational control over a manned space vehicle it had sought since the late 1950s—an arrangement which was quite remarkable, considering that the Air Force had not paid for the development of the STS.

The initial STS spaceflight took place on 12 April 1981 when *Columbia* was launched from KSC. This marked a bittersweet milestone because it was the world's first reusable spacecraft and signified the return of manned American spaceflight. But the STS was also two years behind schedule and cost $2 billion more to develop than originally projected. Moreover, it rapidly became apparent that due to very intensive and difficult refurbishing requirements following each flight, STS could not come close to meeting its planned flight schedule.[107] However, the military potential of the STS was also apparent from the outset. The second STS mission in November 1981 conducted radar-imaging experiments from orbit that pinpointed an ancient city buried beneath the sands of the Sahara and thereby demonstrated the significant military potential of this type of spaceborne sensor.[108] The first classified military payload was carried into

---

continued from the previous page
payloads. Other significant provisions of this MOU indicated that 1) the Air Force was DOD's "sole point of contact with the NASA for all commitments affecting the STS and its use in matters regarding national security space operations and in international defense activities covered by Government to Government agreements"; 2) the Air Force would "develop, acquire, and operate a dedicated Shuttle mission planning, operations, and control facility for national security missions"; and 3) "an STS mission assignment schedule and plan" would be developed to facilitate the "expendable booster transition and phaseout plans" of NASA and the Air Force.

106. Ibid., pp. 3–4, 6–9. Specifically, for category one DOD STS flights, NASA would exercise flight control from JSC, but "NASA will be responsive to DOD Mission Directors," who would retain "overall responsibility for achieving mission objectives." For these missions, Air Force personnel "will be integrated into NASA line functions for training" in order to "allow the USAF to develop the capability to plan, control, and operate national security missions." For category two DOD STS flights, an Air Force Flight Director "will be responsible for overall mission accomplishment and operational control, including flight vehicle and crew safety, through the Air Force chain of command." Although not specified in this MOU, the implication is that category two DOD STS missions would be controlled from the Shuttle Operations and Planning Complex (SOPC) at the Consolidated Space Operations Center at Falcon (now Schriever) AFB.

107. NASA's STS mission models adopted in the early 1980s were far more realistic than the 60 flights per year originally projected for the Shuttle in the early 1970, but they still called for 24 flights per year from the complete four-orbiter STS fleet. In practice, orbiter turnaround time was approximately 60 days rather than the 7 days originally projected, and the turnaround operation required 6,000 people, nearly four times the expected number. There were only 24 total flights in the nearly five years of STS operations prior to the *Challenger* disaster. See E. C. "Pete" Aldridge, Jr., "Assured Access: 'The Bureaucratic Space War,'" Dr. Robert H. Goddard Historical Essay, n.d., p. 5. Offprint provided to author by the Office of the Secretary of the Air Force.

108. Trento, *Prescription for Disaster*, pp. 200–201; Richelson, *Secret Eyes*, p. 219. These first radar-imaging experiments were conducted with Shuttle Imaging Radar (SIR)-A. SIR-B experiments were conducted with updated hardware on mission 41-G in October 1984. According to Richelson, the SIR-A radar could apparently image objects 16 feet beneath dry sand.

orbit aboard *Columbia* during the STS-4 mission in June–July 1982, which also marked the end of the STS flight-testing phase.[109]

Meanwhile, elements within the Reagan administration and Congress were carefully monitoring early STS developments. On 13 November 1981, President Reagan signed National Security Decision Directive (NSDD)-8 that reaffirmed the space transportation policies of the Ford and Carter administrations by stating, "The STS will be the primary space launch system for both United States military and civil government missions. The transition should occur as soon as practical."[110] According to Mark, NSDD-8 also indicated "that the president had a strong personal interest in the space shuttle program."[111] Reagan's first comprehensive space policy, NSDD-42, was publicly announced by the President himself at a 4 July 1982 ceremony at Edwards AFB marking the beginning of the operational phase of STS operations, with *Columbia* in the background. In terms of space transportation policy, NSDD-42 reaffirmed that the STS was the nation's primary launch system, declared that the United States "is fully committed to maintaining world leadership in space transportation," stated that the "first priority of the STS program is to make the system fully operational and cost-effective in providing routine access to space," and indicated that U.S. "government spacecraft should be designed to take advantage of the unique capabilities of the STS."[112] Additionally, this directive indicated that "for the near-term," the STS would be managed under the terms of the NASA/DOD MOUs but as "STS operations mature, options will be considered for possible transition to a different institutional structure."[113] Finally, NSDD-42 made a concession to the NRO: "Unique national security considerations may dictate developing special-purpose launch capabilities."[114]

Early STS operations presented a variety of challenges and opportunities for the Air Force and NRO. Different elements within the Air Force had particular space priorities and viewpoints on the potential of the Shuttle. The space enthusiasts former Secretary Mark had reenergized within the Air Force were excited about exploring the military potential of STS, especially for military

109. Melvyn Smith, *Space Shuttle* (Newbury Park, CA: Haynes Publications, 1989), appendix 7; "Chronology," in *U.S. Military Uses of Space*, p. 52.

110. NSDD-8, "Space Transportation System," 13 November 1981, cited in "Chronology," in *U.S. Military Uses of Space*, p. 51.

111. Mark, *Space Station*, p. 131.

112. NSDD-42, "National Space Policy," 4 July 1982, pp. 2–3, NSC box, National Archives, Washington, DC. Two complete pages and approximately five additional paragraphs are deleted from the sanitized version of this directive. The White House also issued a five-page fact sheet, "National Space Policy," on 4 July 1982, reprinted in NASA, *Aeronautics and Space Report of the President, 1982 Activities* (Washington, DC: GPO, 1983), pp. 98–100.

113. NSDD-42, "National Space Policy," p. 4.

114. Ibid.

man-in-space missions.[115] The NRO was not very happy with being directed to abandon ELVs for STS but was in the process of redesigning and reconfiguring its future payloads to take full advantage of STS's substantial payload capabilities.[116] Other groups within the Air Force were far less excited with space or STS and opposed the substantial Air Force expenditures required to prepare for DOD STS operations. Major Air Force programs designed to support DOD STS operations included the ill-starred Inertial Upper Stage (IUS) program, modifications of SLC-6 at Vandenberg AFB for STS launch, construction of the Space Operations Planning Complex (SOPC) at Falcon AFB, and modifications to the Kennedy, Johnson, and Goddard Space Flight Centers for "controlled mode" DOD STS operations.[117]

115. Military uses of STS are not often or fully discussed in open sources. In answering congressional questions in March 1983, DOD drew a distinction between "payload delivery" and "full exploitation" of STS, defining the latter as follows: "In the longer term, when the capabilities of the Shuttle will be routinely available, the DOD envisions use of the enhanced capabilities unique to the Shuttle, such as on-orbit assembly of large structures; checking out payloads prior to deployment; repairing and servicing of satellites on-orbit; retrieving spacecraft for repairs and refurbishment; and performing man in the loop experiments." See House Committee on Appropriations, Subcommittee on the Department of Defense, *Department of Defense Appropriations for 1984*, Hearings before Subcommittee on Department of Defense, 98th Cong., 1st sess., pt. 8, 1983, p. 508. See also Edward H. Kolcum, "Defense Moving to Exploit Space Shuttle," *Aviation Week & Space Technology* (10 May 1982): 40–42. Kolcum notes that DOD's space test program (STP) experiments (e.g., Teal Ruby) would henceforth use STS rather than ELVs.

116. One of the most sensitive points for NASA regarding STS performance is that it never met its original 65,000-pound payload specification as set in conjunction with the Air Force in the early 1970s. The NASA STS performance data in the *President's Space Report* for 1981–87 indicated that the STS was able to boost approximately 65,000 pounds "in full performance configuration." However, the figure in the *Aeronautics and Space Report of the President* for 1988 (after resumption of STS operations) indicated a significant drop in STS full-performance configuration capabilities to approximately 54,895 pounds. Moreover, during congressional testimony in 1981, Air Force Assistant Secretary and NRO Director Robert J. Hermann indicated that "current projections of Shuttle performance show it to be about 8000 lbs lower than the original commitment. DOD missions can profitably use the full capability of the original performance commitment" (Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science, Technology, and Space, *NASA Authorization for Fiscal Year 1982*, Hearing before the Subcommittee on Science, Technology, and Space, 97th Cong., 1st sess., pt. 2, 1981, p. 349). In 1982, Aldridge, Hermann's successor as NRO Director, indicated that the first Vandenberg AFB Shuttle launch scheduled for October 1985 "will require full specification Shuttle performance—as called out in our Performance Reference Mission 4 requirements. Specifically, the Shuttle must be capable of delivering 32,000 pounds to a 98 degree inclined, 150 nautical mile circular orbit and, then, recover another satellite weighing 25,000 pounds and return it to Vandenberg. The Shuttle with its current performance estimate cannot achieve this long standing defense requirement" (prepared statement of Under Secretary Aldridge in Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science, Technology, and Space, *NASA Authorization for Fiscal Year 1983*, Hearing before the Subcommittee on Science, Technology, and Space, 97th Cong., 2nd sess., 1982, p. 166). Later, Aldridge simply indicated that the "final Shuttle capabilities were nearly 20% short" of NASA's originally promised "65,000 pounds of payload to low earth orbit from Kennedy Space Center and 32,000 pounds to a polar orbit from Vandenberg AFB, California." See Aldridge, "Assured Access," p. 3.

117. See Senate Committee on Commerce, Science, and Transportation, *NASA Authorization for Fiscal Year 1982*, pp. 340–341, 346–350, 444, 484. At this time (April 1981), the first STS launch from Vandenberg

continued on the next page

Despite these widespread efforts and considerable expenditures, the Air Force and DOD basic positions on how the STS fit into long-range military space plans or doctrine remained far from clear, at least in the available unclassified material. Undoubtedly, the basic Air Force overall organizational ambivalence towards space missions was a factor in structuring the long-term Air Force relationship with the STS, especially in light of all the rejected military man-in-space programs the Air Force had previously proposed.

In the early 1980s, former astronaut, space enthusiast, and Space Subcommittee Chairman Senator Harrison Schmitt (R-New Mexico) was among those most clearly upset with the apparent lack of Air Force long-range planning for STS use. During exchanges with Air Force and DOD witnesses at congressional hearings in 1981, Schmitt charged that "historic inertia" as well as "the lack of an organizational focus that has [space] as a primary mission" had made the Air Force "relatively slow to grasp the opportunities that the Space Shuttle provides, not only as a launch vehicle, but as a test and operational vehicle in space."[118] Moreover, Schmitt opined that "within a few years, you all are going to come back in and say 'We need a dedicated shuttle fleet.' And it's painted blue that we could use for our purposes."[119] Further, he warned that unless the Air Force pursued space missions more aggressively, "I can almost predict that there is going to be another Department of Something in the Department of Defense. And the Air Force will be flying airplanes, and not Shuttles."[120]

More widespread congressional concern in 1982 focused on Air Force–NASA relations in regard to the question of whether the U.S. should procure a fifth STS orbiter vehicle before the Rockwell orbiter production lines shut

---

continued from the previous page

was scheduled for August 1984. Assistant Secretary Hermann indicated that the term *controlled mode* "signifies that we are protecting the classified information used in the planning and execution of a DOD mission by controlling access to it. The modifications include construction changes to the buildings to isolate certain areas, the procurement of additional equipment, and the shielding of certain equipment to preclude electronic eavesdropping." He also stated, "All defense payloads will have completed their transition to use of the Space Shuttle as the primary launch vehicle by 1987." The SOPC was to "provide the management and control needed for our national security space operations in the post-1985 timeframe." Additionally, the SOPC would provide a backup to the single STS control node at JSC and would "provide a maximum opportunity to fully exploit the Shuttle unique capabilities, in particular the presence of military man in space." At these same hearings, Dr. James Wade, Acting Under Secretary of Defense for Research and Engineering, estimated that all of the DOD STS-related activities would cost approximately $3 billion through FY 1986. In March 1983, DOD provided figures indicating that "DOD's portion ($15.2 billion) of the total STS cost ($51.1 billion) is 30 percent [these figures are projected through FY 1988]." See House Committee on Appropriations, *Defense Appropriations for 1984*, p. 513. On the Air Force's STS-related expenditures and infrastructure, see also William P. Schlitz, "USAF's Investment in the National Space Transportation System," *Air Force Magazine* 65 (November 1982): 106–112.

118. Senate Committee on Commerce, Science, and Transportation, *NASA Authorization for Fiscal Year 1982*, pp. 458–459.

119. Ibid., p. 447.

120. Ibid., p. 460.

down. Many believed that it would be wise to procure a fifth orbiter as a backup and to provide greater STS capability.[121] The Air Force was very interested in producing another of the lighter weight and more capable orbiters but was unwilling to use DOD funds to procure this fifth orbiter.[122] Meanwhile, NASA was less supportive of the need for a fifth orbiter, largely because Administrator James Beggs and Deputy Administrator Mark had privately agreed that NASA should push a permanently manned space station as the nation's new major civil space goal and were therefore unwilling to take on other major new projects at this time.[123] By the end of 1982, despite considerable congressional support for a fifth orbiter, the NASA compromise solution of keeping the Rockwell lines partially open to produce spare parts won out, and the decision to build a fifth orbiter was deferred.[124] This decision was formalized by NSDD-80, issued on 3 February 1983.[125]

During 1983 and 1984, NRO Director Aldridge waged a mostly secret and very difficult, but eventually successful, campaign against NASA to obtain approval to develop a new ELV capable of launching the spy satellites designed to fit into the STS.[126] Building upon the opening in NSDD-42 to consider building "special-purpose launch capabilities" for "unique national security considerations," on 23 December 1983 Aldridge issued a memorandum, "Assured

---

121. Those favoring a decision to build another orbiter at this time also used arguments about the economic impact of keeping the Rockwell production lines open and the lower costs of building a fifth orbiter in sequence. In *Prescription for Disaster*, Trento speculates that a decision to build the fifth orbiter at this time (with the lines open) would have cost approximately $1.2 billion instead of the $2.1 billion that the fifth orbiter (*Endeavour*) actually cost; see p. 205.

122. See, for example, the testimony of Major General James Abrahamson (NASA Associate Administrator for Manned Spaceflight) and Air Force Under Secretary Aldridge in House Committee on Science and Technology, Subcommittee on Space Science and Applications, *The Need For a Fifth Space Shuttle Orbiter*, Hearing before the Subcommittee on Space Science and Applications, 97th Cong., 2nd sess., 15 June 1982.

123. Mark, *Space Station*, pp. 121–122; Trento, *Prescription for Disaster*, pp. 180–181. Following a long NASA campaign within the administration, President Reagan announced in his 1984 State of the Union Address the national goal of building a permanently manned space station (*Freedom*) within 10 years.

124. Trento, *Prescription for Disaster*, p. 205. On congressional support for a fifth orbiter, see, for example, the position of many Representatives in House Committee on Science and Technology, *Need For a Fifth Space Shuttle Orbiter*, as well as the formal recommendation for a fifth orbiter in House Committee on Science and Technology, Subcommittee on Space Science and Applications, *The Need for an Increased Space Shuttle Orbiter Fleet*, 97th Cong., 2nd sess., 1982, Committee Print Serial HH.

125. William Clark, NSDD-80, "Shuttle Orbiter Production Capability," 3 February 1983, NSC box, National Archives, Washington, DC. Specifically, this one-page directive indicated that a warm production line would "be achieved through the production of structural and component spares necessary to insure that the Nation can operate the four Orbiter fleet in a robust manner."

126. The intense NRO-NASA struggles of this period (a "bureaucratic space war") are the primary focus of Aldridge, "Assured Access," pp. 3–15. Naturally, this piece covers the positions of Aldridge and the Air Force far more sympathetically than the positions of Beggs or NASA, but it is by far the most detailed description of developments surrounding the CELV decision uncovered during research for this study.

Access to Space," to Air Force Space Command and Space Division.[127] This memorandum directed these organizations to plan for the procurement of a complementary ELV (CELV) capable of boosting a payload the size of the STS cargo bay and weighing 10,000 pounds into geosynchronous transfer orbit.[128] According to Aldridge, NASA Administrator Beggs "was furious" with these developments and saw them as "only a ploy of the Air Force to abandon the Shuttle."[129] However, in August 1984, Aldridge's position was formally supported by the NSC in NSDD-144 that approved Air Force development of the CELV.[130] Nonetheless, Beggs and NASA continued to oppose the CELV option and enlisted considerable congressional support in opposition to the CELV.[131]

Aldridge notes that the NSC staff hosted "the *critical* meeting" on the CELV issue on 14 February 1985.[132] At this meeting, Aldridge and Beggs finally reached agreement. This agreement was reflected in NSDD-164, issued on 25

127. "Chronology," in *U.S. Military Uses of Space*, p. 55. The primary rationale behind developing such a capability was to avoid dependence on a single system for space launch. Additionally, the final Air Force ELV buys were being completed at this time, and the production lines were in danger of being shut down unless new orders were found.

128. Ibid. Secretary Caspar Weinberger outlined a new DOD space launch strategy relying on a mixed fleet of ELVs and the STS in a letter to the President on 7 February 1984; see Aldridge, "Assured Access," p. 6.

129. Aldridge, "Assured Access," p. 6.

130. "Chronology," in *U.S. Military Uses of Space*, p. 56. Presumably, NSDD-144 was the subject of the White House fact sheet "National Space Strategy," issued on 15 August 1984 and reprinted in *Aeronautics and Space Report of the President, Fiscal Year 1984*, pp. 137–139. According to this fact sheet, the directive specified two requirements for "assured launch capability": "the need for a launch system complementary to the STS to hedge against unforeseen technical and operational problems, and the need for a launch system suited for operations and crisis situations." However, there is some confusion about at least the number of this classified directive in open sources. Scott Pace, in "US Space Transportation Policy: History and Issues for a New Administration," *Space Policy* 4 (November 1988): 307, 309, indicates that NSDD-144, "National Security Launch Strategy," was not issued by the EOP until 28 February 1985. Aldridge does not discuss this directive in "Assured Access." NSDD-144 was not available in the NSC box at the National Archives.

131. According to Aldridge, NASA had several concerns with and employed several tactics against the CELV. NASA felt that if DOD moved away from the STS, the costs per launch would increase and NASA would need to charge its commercial customers more for each launch. This, NASA officials thought, would drive more commercial customers towards the Ariane. In an 18 May 1984 letter from Administrator Beggs to Secretary Weinberger, NASA indicated that an STS backup was not necessary but that if DOD was determined to build a new launch vehicle, it should be derived from STS components. Next, NASA supporters in Congress specified that a competition would be run between NASA designs and industry designs for a system to meet Air Force requirements. Aldridge claims in "Assured Access" that NASA put subtle pressure on its suppliers not to compete against its Standardized Launch Vehicle (SLV-X) by indicating that their behavior would have consequences for future NASA purchases. A modified Titan III called a Titan 34D7 was the winner in the industrial competition conducted by the Air Force, while the NASA entry was judged by the Air Force Space Division to be uncontrollable during the boost phase of flight. Finally, as the ELV production lines were beginning to shut down, NASA recommended that several major and lengthy studies be undertaken on the CELV issue as a delaying tactic ("Assured Access," pp. 7–13).

132. Ibid., p. 13, emphasis in original.

February 1985.[133] Specifically, NSDD-164 authorized the Air Force to buy 10 CELVs and to launch approximately 2 CELVs per year in the period 1988–92.[134] Thus, Aldridge won his victory in the bureaucratic space war less than one year prior to the complete reordering of U.S. space transportation policy caused by the *Challenger* disaster.

In hindsight, given large impact of the *Challenger* disaster, it is remarkable that there was such sustained opposition to acquiring a backup capability for the STS. Moreover, while access to space is a prerequisite for any space activity, it is unfortunate that Aldridge and the top levels of Air Force space leadership, as well as much of NASA's leadership, were largely consumed with this issue during the mid-1980s rather than focusing on broader, more important, or more future-oriented space policy issues. Finally, it is also interesting to note that many groups were dissatisfied with STS performance capabilities and especially the mounting STS payload backlog of the mid-1980s but that only the NRO had the clout to develop a new ELV and move its most important payloads off the STS.[135]

The *Challenger* disaster completely reordered U.S. space transportation policy and effectively deferred any Air Force plans to use STS as a vehicle to build a significant manned military presence in space. During 1986 and 1987, NASA, DOD, and the newly formed Office of Commercial Space Transportation (OCST) within the Department of Transportation worked together to produce a new U.S. space launch strategy and the Space Launch Recovery Plan. NSDD-254, "United States Space Launch Strategy," was completed on 27 December 1986.[136] This directive specified that the U.S. would henceforth rely upon a

133. NSDD-164, "National Security Launch Strategy," 25 February 1985, NSC box, National Archives, Washington, DC. This unclassified directive was publicly released on 14 November 1985.

134. Ibid., p. 1. NSDD-164 also 1) indicated that a "competitive decision" on a specific CELV would be made by 1 March 1985, 2) directed that "DOD will rely on the STS as its primary launch vehicle and will commit to at least one-third of the STS flights available during the next ten years," 3) directed NASA and DOD to "jointly develop a pricing policy for DOD flights that provides a positive incentive for flying on the Shuttle," and 4) authorized a joint NASA-DOD effort to produce a national security study directive (NSSD) on the development of "a second-generation space transportation system."

135. Some of the strongest opposition to STS "forced busing in space" came from within NASA's own space science community. NASA had directed that all its payloads be launched exclusively by the STS, but by the mid-1980s, the STS backlog and problems with the STS upper stages were causing multiyear delays and significant design changes for key space science projects such as the Galileo Jupiter probe and the Hubble Space Telescope. See, for example, Bruce Murray, "'Born Anew' Versus 'Born Again,'" in "Policy Focus: National Security and the U.S. Space Program After the Challenger Tragedy," *International Security* 11 (spring 1987): 178–182. Even more significantly, because STS was not providing low-cost launch rates (even at its generous pre-*Challenger*-disaster subsidized rates) or reliable service and launch schedules, commercial customers were "voting with their feet" and moving in increasing numbers onto the more commercially viable Ariane ELV.

136. NSDD-254, "United States Space Launch Strategy," 27 December 1986, NSC box, National Archives, Washington, DC. Approximately three sentences of this two-page directive are deleted in the sanitized version. The White House released a fact sheet on this directive on 16 January 1987. NSDD-254 superseded NSDD-164.

"balanced mix of launchers" consisting of the STS and ELVs defined "to best support the mission needs of the national security, civil government and commercial sectors of U.S. space activities."[137] Further, "selected critical payloads will be designed for dual-compatibility, i.e., capable of being launched by either the STS or the ELVs."[138] In order to accomplish these objectives, the directive indicated that DOD "will procure additional ELVs to maintain a balanced launch capability and to provide access to space."[139]

The Space Launch Recovery Plan dealt with the means to implement this new launch strategy in greater detail. The plan focused on the revitalization of the nation's ELV production base and attempted to use government ELV purchases as a means to stimulate the development of a more robust commercial ELV industry. The plan also provided $2.1 billion to NASA for the production of a fifth orbiter, *Endeavour*, to be ready for flight by 1992. In addition, under this plan, the Air Force completely reoriented its future space support infrastructure and plans. The Air Force launched a $12-billion program to initiate or expand four ELV programs.[140] These Air Force ELV programs included expansion of the original 10 booster CELV program to 41 Titan IVs, two medium launch vehicle programs consisting of 20 Delta 2 and 11 Atlas-Centaur 2 ELVs, and refurbishing 14 decommissioned Titan II ICBMs for space launch.[141] Additionally, the Air Force took drastic steps to reconfigure the infrastructure it had developed to operate DOD STS missions, including placing the unused SLC-6 at Vandenberg AFB into "minimum facility caretaker" status in July 1986, eliminating the 32-member-strong Manned Spaceflight Engineer (MSE) program within the Space Division, disbanding the Manned Spaceflight Control Squadron at the JSC as of 30 June 1989, and ending development of the SOPC at CSOC in February 1987.[142] Further, as a result of this plan, the DOD scheduled only seven

137. Ibid., p. 1.

138. Ibid.

139. Ibid. Additionally, NSDD-254 specified that NASA would no longer provide commercial or foreign launch services on the STS "unless those spacecraft have unique, specific reasons to be launched aboard the Shuttle." The directive also set a 1995 "commercial contract mandatory termination date." This policy meant that of the 44 commercial and foreign launch commitments NASA had in January 1986, only 20 of these payloads still qualified for STS launch. See *Aeronautics and Space Report of the President, Fiscal Year 1986*, p. 33.

140. Pace, "US Space Transportation Policy," p. 310.

141. Ibid.; William J. Broad, "Military Launches First New Rocket for Orbital Loads," *New York Times* (6 September 1988): 1; Joint Statement of Air Force Secretary Aldridge and Chief of Staff General Larry D. Welch in Senate Committee on Appropriations, Subcommittee on Department of Defense, *Department of Defense Appropriations for Fiscal Year 1988*, Hearings before the Subcommittee on Department of Defense, 100th Cong., 1st sess., pt. 3, 1988, pp. 301–303.

142. William J. Broad, "Pentagon Leaving Shuttle Program," *New York Times* (7 August 1989): A13. Broad estimated the costs for these programs to be "at least $5 billion," the lion's share of which was the $3.3-

continued on the next page

dedicated STS launches for the period 1991–95 and thereafter planned to rely almost exclusively on ELVs.[143]

The relationships between the Air Force, DOD, and NASA over STS operations were clearly marked by great difficulties during the 1980s. The development of military space launch policy during this period provides one of the most powerful instances of organizational behavior inputs shaping U.S. space policy and significantly impacting military space doctrine. Despite building a large and expensive infrastructure for launching and controlling DOD STS missions, the Air Force never fully exercised this capability prior to the *Challenger* disaster, and, following the disaster, the Air Force and NRO were instrumental in leading DOD's rush off the STS in favor of ELVs. The bitter fight with NASA over the CELV and the general desire to fully control its launch vehicles were important factors in motivating this Air Force space launch policy reversal; however, the speed and complete nature of the virtual abandonment of the STS and the significant infrastructure designed to support DOD STS missions is remarkable and not well explained in open sources. The lack of clear and powerful military space doctrine undoubtedly contributed to these false starts, reversals, and lack of clear direction for the DOD STS mission. Cumulatively, this episode seems to be an excellent illustration of the general Air Force ambivalence over the military potential of space and military man-in-space, as well as evidence of its lack of clear and accepted doctrinal guidance on these issues.

continued from the previous page
billion SLC-6 at Vandenberg AFB. The SOPC building at CSOC was converted into the National Test Bed (now the Joint National Integration Center) for the Strategic Defense Initiative (SDI) program. As Broad relates, military space critics such as John Pike of the Federation of American Scientists charged that the Air Force went overboard in developing new ELVs and abandoning the STS.

143. Pace, "US Space Transportation Policy," p. 310. The first Titan IV launch took place on 14 June 1989 from Cape Canaveral; see "Chronology," in *U.S. Military Uses of Space*, p. 61.

Chapter 8

Technology, Foreign Policy, and International Cooperation in Space

John Krige

International cooperation has always been part of NASA's mission.[1] But why? Why is it in NASA's and America's interest to collaborate with foreign partners? The question is not as perverse as it sounds. In 1958, the United States was, and probably still remains, the single most important economic and military, but also scientific and technological, as well as industrial and managerial, power on Earth. Those to whom Eisenhower confided the civilian space program drew, though NACA, on a vast and expanding infrastructure of scientists, engineers, and managers, along with the facilities and the budget to match it, especially once President Kennedy committed the country to putting a person on the Moon before 1970. With some important exceptions—like the need for a global network of tracking stations, or sounding-rocket studies of the properties of the upper atmosphere in equatorial regions—there was no overriding scientific or technical (and certainly no financial) reason why NASA and the United States needed to collaborate with any other country in the conquest of space. Unlike small and medium-sized European states, America was rich enough in human and material resources to go it alone, and as such was the envy of all aspirant space powers (except perhaps the Soviet Union, who had to cripple its domestic economy to maintain its military and space capabilities at some sort of parity with those of the U.S.A.).

One classical argument for international collaboration was that it would improve relationships between the United States and the Soviet Union. The decision to establish NASA was, of course, just one of a number of measures taken by the Eisenhower administration to calm the nation in response to the engineered domestic crisis that ensued in the wake of the launch of the Sputniks by the Soviet Union in the fall of 1957. Superpower rivalry was at its height: by the end of the 1950s, each country knew that it could strike a

1. For a fine overview of NASA's international program, with supporting key documents, see John M. Logsdon, "The Development of International Space Cooperation," chap. 1 in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program,* ed. John M. Logsdon, with Dwayne A. Day and Roger D. Launius, vol. 2, *External Relationships* (Washington, DC: NASA SP-4407, 1996).

lethal blow at the other using nuclear-tipped missiles. This balance of terror provided one of the most frequent arguments at the time for international space cooperation. As Lyndon Baines Johnson, then the Majority Leader of the Senate, put it in 1959, "If . . . we proceed along the orderly course of full cooperation, we shall by that very fact of cooperation make the most substantial contribution yet made towards perfecting peace. Men who have worked together to reach the stars are not likely to descend together into the depths of war and desolation."[2] This claim, the conviction that international space cooperation with the Soviets would remove misunderstanding, project a positive image of the U.S. abroad, reduce tension, and advance the cause of world peace was a *leitmotif* of the early arguments for an international component to the space program. It was also used by Richard Nixon, who justified the expansion of U.S.-Soviet space collaboration in the early 1970s as creating "not just a climate for peace," but the "building blocks" for "an actual structure of peace and cooperation."[3]

This rhetoric did not carry much weight with some people, notably Arnold Frutkin. Frutkin, who was responsible for international affairs inside NASA for 20 years, beginning in 1959, was emphatic about this.[4] "Now, I hope it's come through," he said towards the end of a long interview conducted a few years ago, "that I am not soft-headed about dealing with other people—[like] if you knew your neighbor better you'd like him. I never believed that. If you knew your neighbor better," Frutkin went on, "you might conclude that he [was] a worse son of a bitch than you [suspected]."[5] Frutkin spoke from bitter experience: after many years of achieving little more than "arm's-length" cooperation with the Soviets—more may have been possible had Kennedy not been assassinated—he had finally been witness to the famous Apollo-Soyuz "hand shake in space" in July 1975.[6] For him, while international space

2. Quoted in Don E. Kash, *The Politics of Space Cooperation* (n.p.: Purdue University Studies, 1967), p. 10.

3. The words are those of Ron Ziegler, the President's press secretary, during a press conference at the White House on the "Agreement Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes," 24 May 1972, record no. 12594, Presidential Files, NASA Historical Reference Collection, Washington, DC.

4. Arnold W. Frutkin was deputy director of the U.S. National Committee for the International Geophysical Year in the National Academy of Sciences before he joined NASA in 1959 as director of international programs. His official title changed in 1963 to Assistant Administrator for International Affairs. In 1978, Frutkin became Associate Administrator for External Relations. He retired from federal service in 1979.

5. Arnold W. Frutkin interview, Washington, DC, by Rebecca Wright, 11 January 2002, NASA Historical Reference Collection, Washington, DC.

6. In the early years of his presidency, Kennedy made extensive overtures to the Soviets backed by behind-the-scenes negotiations that seemed to be making considerable headway. These were abruptly stopped after his death—see particularly National Security Action Memorandum 271, dated 12 November 1963 and reproduced in Logsdon, "International Space Cooperation," pp. 166–167.

cooperation was a widely endorsed scientific and political objective, it also was also victim of a multitude of "abstractions, moral imperatives, and contrived prescriptions."[7]

Contemporary analyses of the U.S.'s motives for collaborating in space combine a refreshing spirit of *realpolitik* when discussing how the U.S. *has* behaved in the past with a tendency to prescriptive injunctions about how NASA *should* behave in the future, which Frutkin would probably deplore. We shall treat each of these dimensions of this body of literature in turn.

There is something of a consensus that, for the first two or three decades of its existence, NASA, by virtue of America's immense scientific and technological advantage vis-à-vis its partners, could use its power to dictate the terms of any significant international space effort. American hegemony was implicit in the 1958 Space Act which established NASA and which defined the organization's primary objective as being "the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof."[8] This concept of leadership, we were reminded in 1987 by a task force of the NASA Advisory Council (NAC), chaired by Herman Pollack, meant not simply achieving superior performance in all aspects of space. It also meant "the defining of goals and the establishment of direction that *others w[ould] be willing to make their own or follow*" (emphasis added).[9] To the U.S., according to another group of space activists, for the first two decades after Sputnik, "cooperation was a politically driven means of linking the space programmes of other countries to US goals and activities, rather than having them closely allied with Soviet aspirations in space."[10] Political scientist Joan Johnson-Freese makes a similar point: in the Cold War context of the '60s and '70s, the U.S. actively sought to collaborate with its Western bloc allies and countries that it wanted to attract to the Western alliance. And since it was "dominant in space, it could dictate terms of cooperation to other countries, which they were more than willing to accept in order to gain entrance to the space program."[11]

Scientific research was a privileged site for international collaboration, and Frutkin quickly defined a set of five criteria which guided NASA's policy in this domain and which embodied these precepts.[12] His criteria are well known

7. Arnold W. Frutkin, "International Cooperation in Space," *Science* 169 (24 July 1970): 333–339.

8. National Aeronautics and Space Act of 1958 (Unamended), Sec. 102 (c) (5), available online at *http://www.hq.nasa.gov/office/pao/History/spaceact.html* (accessed 27 January 2005).

9. Herman Pollack, "International Relations in Space. A US View," *Space Policy* 4, no. 1 (February 1988): 24–30.

10. Space Policy Institute and Association of Space Explorers, "International Cooperation in Space—New Opportunities, New Approaches," *Space Policy* 8, no. 3 (August 1992): 195–203.

11. Joan Johnson-Freese, *Changing Patterns of International Cooperation in Space* (Malabar, FL: Orbit, 1990), p. 5.

12. Arnold W. Frutkin, *International Collaboration in Space* (Englewood Cliffs, NJ: Prentice Hall, 1965).

and need not be rehearsed here. Suffice it to say that Frutkin's stress on the need for clean interfaces and no exchange of funds between the partners was inspired by the need to limit technological (and managerial) sharing between the U.S. and its partners to a minimum. Even the content of the program had to dovetail with U.S. interests. As Logsdon puts it, being the dominant partner in space science "often meant that NASA and U.S. scientists would define the objectives and content of a scientific mission and only then invite non-U.S. scientists to participate."[13] Even then, NASA sometimes pulled the plug on a well-defined joint international project to meet domestic pressures for budget cuts and the redefinition of priorities.[14]

Scientific collaboration was the most readily available and least controversial instrument of international collaboration, but it was not enough, particularly in dealing with major allies like Western Europe. The U.S. technological lead and the dynamism of American industry allowed the administration to think beyond the limits of scientific collaboration and to use its technological assets, including technological knowledge and skills, as an instrument of foreign policy to consolidate the Atlantic alliance. Put differently, if the U.S. pursued international collaboration, it was because it "sought the political benefits of leadership [while] its partners [sought] the technical and managerial benefits that come from working with the leader."[15] Here lies the soft underbelly of technological collaboration in the space sector. For if the benefit was in foreign policy, as the Pollack Task Force stressed, the cost lay in the risk that technological sharing would subvert U.S. leadership by helping allies to assert themselves, would endanger national security in a sector where almost all satellite and booster technology is "dual-use technology," and would endanger U.S. industry in a crucial high-tech sector.

Once we move beyond scientific collaboration to technological sharing, those who promote international cooperation will be on the defensive. They will have to overcome the opposition of counterforces that stress the threats to the U.S. that such collaboration entails. These critics will point out that if America's allies are willing to be dependent on the U.S. in the short term, it is with the long-term aim of being autonomous. That if those allies accept the hegemonic regime imposed by the U.S., it is in the hope that they will eventually be able to throw off its yoke. And that if they collaborate initially on terms which are not of their own choosing, it is in order later to compete better with the United States as equal partners, or even to become leaders in areas where America was previously supreme. In short, international col-

13. Logsdon, "International Space Cooperation," p. 4.

14. For an angry account of this by two ESA insiders, see Roger M. Bonnet and Vittorio Manno, *International Cooperation in Space: The Example of the European Space Agency* (Cambridge, MA: Harvard University Press, 1994).

15. Space Policy Institute and Association of Space Explorers, p. 200.

laboration in space is always a contested policy objective. It will always have to justify itself to critics who will ask, as I did at the start of this paper, "But why collaborate?" and who see little reason for risking national security and industrial competitiveness, which are essential for the long-term strength of the country, in return for the fragile and unpredictable foreign policy benefits that international collaboration putatively enshrines.

This domestic political context informs much of the literature on international cooperation and accounts for the prescriptive dimension alluded to above. It is dominated by activists, administrators, and political scientists who combine their sense of *realpolitik* with a wish to influence the way NASA and the United States behave in current international collaborative projects, notably the negotiations on foreign participation in the International Space Station. All are sensitive to the changed balance of power in the space sector: the collapse of the Soviet Union as a rival superpower (which forced a major reevaluation of one of NASA's original goals) and the technological and managerial maturity achieved by space programs in the U.S.'s traditional allies (notably Western Europe and Japan). All are also convinced that international collaboration is a worthwhile goal and that, to maintain American leadership in at least certain key areas, the U.S. will have to change its attitudes to meet the changed environment of the late 20th century. Thus Joan Johnson-Freese: "Because the United States began as the dominant space power concerning cooperative ventures, it has never had to learn to operate in any manner other than 'the U.S. way'. But things have changed," she goes on. "There are now an increasing number of space 'actors' with varying ranges of capabilities," including the Soviet Union, Japan, and Western Europe, and "the United States is no longer 'the only game in town' in space activities, although in some cases it is still trying to act as though it is."[16] So, too, the Task Force chaired by Pollack in 1987: "The USA will have to adopt [*sic*] its attitude, approach and politics on international cooperation and competition to a new set of realities."[17] And Ken Pederson, who was responsible for NASA's International Affairs Division in the 1980s and who gave some concrete examples of what that meant. "For NASA today," he wrote, "'power' is much more likely to mean the power to persuade than the power to prescribe." This entails 1) that NASA must accept that "leadership does not mean that it must or ought do it all"; 2) that even if it is the provider of major hardware, NASA "may sometimes have to accept the role of junior partner rather than managing partner" and understand that it can still benefit while doing so; and 3) that NASA must "learn to share direct management and operational control in projects where it is the largest hardware and financial contributor, especially when manned flight systems are involved."[18]

16. Johnson-Freese, p. 113.

17. Pollack, "International Relations in Space."

18. Ken Pedersen, "The Changing Face of International Space Cooperation. One View of NASA," *Space Policy* 2, no. 2 (May 1986): 120–137.

This stream of modal concepts, this prescriptive discourse is situated at the core of the struggle to define the U.S.'s role in space in the 21st century and intended to reshape its practices in the international domain. These advocates believe that space cooperation is a "good thing" for the United States, and they seek to lay down the ground rules, based on past experience, for what the U.S. "must do" if it wants to retain credibility and leadership as an international partner. And while commendable for their sensitivity to the points of friction which have traditionally irritated America's partners, their proposals also have an air of unreality. *It is indeed striking that, while all of these authors stress that the U.S. international space effort is driven by foreign policy and that technological collaboration is a substantive issue which shapes its physiognomy, none of them deal with foreign policy or technology except in the most generic way*. These are a taken-for-granted backdrop against which their prescriptions are made, a context which, precisely, cannot be taken for granted, for it is the always-contested framework in which stakeholders will decide whether to collaborate internationally at all, let alone on the terms, and respecting the "musts," that the advocates promote so skillfully.

Scientific and technological sharing, and foreign policy concerns, are the material substrates of international collaboration in space. Scientific and particularly technological sharing, both of hardware and of knowledge and skills, are the single most important means that the U.S. has to influence the space programs of other countries, so consolidating and legitimating its leadership and its hegemonic regime. Technological sharing is also the single greatest danger to national security and national industrial competitiveness in a crucial high-technology sector. The onus on those who promote international collaboration in space is to show how the sharing of specific technologies and the knowledge embedded in them will further America's leadership abroad in a particular historical conjuncture and why that objective will not unduly jeopardize national industry or undermine national security. To advance this debate, one cannot "black-box" technology and foreign policy: they are not the context in which international collaboration takes place; they are the stakes that define what is possible.

This paper aims to contribute to our understanding of international collaboration by using an illustrative historical case study to open the black box of technology and of foreign policy.[19] At the risk of oversimplifying an extremely complex debate, I will explain briefly why the Johnson administration decided in the mid-1960s that it was imperative to collaborate with Western Europe in developing a civilian satellite launcher and discuss the kind

19. The case study presented here is based on a small subset of a huge number of documents retrieved from the archives preserved in the NASA Historical Reference Collection in Washington, DC, and at the Lyndon Baines Johnson Library in Austin, TX (hereafter LBJ Library). Additional material was acquired from the National Archives and Records Administration in College Park, MD. I would like to thank the archivists for their invaluable help and support.

of technological sharing that some people thought might be used to achieve the President's foreign policy objectives.[20] What I want to emphasize above all is the strong coupling between technology and foreign policy. I also want to insist that, to understand the possibilities of international collaboration in space, it is crucial to focus on what *specific* technologies might be available for sharing in the pursuit of *specific* foreign policy objectives, rather than—as so often happens—to simply lump technology and foreign policy into an undifferentiated whole. Those in the administration who are engaged in working out what can be done with a foreign partner fight over the boundary between what technologies can be shared and what cannot. The advocates of a more open approach are driven by the conviction that the maintenance of American "leadership" and its ability to control the form and content of the space programs of other nations are best achieved by relaxing restrictions in particular areas. Sometimes they win; sometimes, as in the case to be described here, they lose, both because the forces arraigned against them are formidable and because the foreign policy context is never stable and calls forth a different response to changed circumstances. I am convinced that only if historians study international collaboration at this fine-grained level can they help avoid what Frutkin bemoaned over 30 years ago, namely, analyses replete with the "usual quota of abstractions, moral imperatives, and contrived prescriptions."

THE JOHNSON ADMINISTRATION AND THE ELDO CRISIS

On 29 July 1966, Walt W. Rostow, one of LBJ's two national security advisers, signed off on National Security Action Memorandum 354.[21] NSAM 354 was a response to a request from the Department of State that the U.S. "clarify and define" its policy concerning collaboration with the "present and future programs" of ELDO, the European Launcher Development Organisation. The document affirmed that it was "in the U.S. interest to encourage the continued development of ELDO through U.S. cooperation." It referred to the results of an ad hoc working group, established by the State Department and chaired by Herman Pollack, that had prepared a statement "defining the nature and extent of U.S. cooperation with ELDO which the U.S. government is now prepared to extend." This statement was to be "continually reviewed by the responsible agencies," above all, the Department of

20. The reactions in the United States to the ELDO crisis in 1966 have received little scholarly attention. For the best analysis, see Lorenza Sebesta, *Alleati Competitivi. Origini e sviluppo della cooperazione spaziale fra Europa e Stati Uniti* (Bologna, Italy: Laterza, 2003), chap. 3. The issue is also described in a project Sebesta worked on with John M. Logsdon. I thank John Logsdon for making a copy of their unpublished manuscript available to me.

21. NSAM 354, "U.S. Cooperation with the European Launcher Development Organization," 29 July 1974, available online at *http://www.lbjlib.utexas.edu* (accessed on 9 March 2005).

Defense and the State Department, along with NASA, "to ensure that it is current and responsive in terms of developing strategies."

The help that the working group proposed was extensive. It was divided into three categories: general, and short-range and long-range assistance.[22] The first contained some standard items—training in technical management, facilitating export licenses, use of NASA test facilities—but also suggested that a technical office be established within NASA "specifically to serve in an expediting and assisting role for ELDO." Short-range help included "technical advice and assistance" in items like vehicle integration, stage separation, and synchronous orbit injection techniques, as well as the provision of unclassified flight hardware, notably a strapped-down "guidance" package used on the Scout launcher which had already been exported to Japan. Long-range assistance was focused on helping with a high-energy cryogenic upper stage of the rocket, currently being considered in ELDO. It was proposed that Europeans be given access to technological documentation and experience available in the Atlas-Centaur systems, that ELDO technical personnel "have intimate touch with the problems of systems design, integration, and program management of a high-energy upper [*sic*] such as the Centaur," and even that the U.S. consider "joint use of a high-energy upper stage developed in Europe."[23] In short, in mid-1966, the U.S. was considering making a substantial effort to help ELDO develop a powerful launcher with geosynchronous orbit capability by sharing state-of-the-art knowledge and experience and by facilitating the export of hardware which—it should be added—would not normally be available on a bilateral basis to European national launcher programs.

NSAM 354 was catalyzed by a crisis in ELDO in February 1966 and deep concerns in the Johnson administration about the future of the collaborative European effort. ELDO, it must be said, had been a fragile organization from its very inception in 1960–61.[24] It was born of the need by the British government to find a new role for its Blue Streak missile. The liquid-fueled rocket was rendered obsolete by the long time required to prepare it for launch and

---

22. This paragraph is derived from "Policy Concerning US Cooperation with the European Launcher Development Organization (ELDO)," attached to U. Alexis Johnson's "Memorandum," 10 June 1966, folder 15707, International Cooperation and Foreign Countries, NASA Historical Reference Collection, Washington, DC.

23. In summer 1965, ELDO had asked for help from NASA on "designing, testing and launching liquid hydrogen/liquid oxygen upper stages" (Frutkin to Robert N. Margrave, Director, Office of Munitions Control, Department of State, 6 June 1965, record no. 14465, International Cooperation and Foreign Countries, International Cooperation, folder International Policy Manual Material from Code I, NASA Historical Reference Collection, Washington, DC).

24. I describe the launch of ELDO in detail in J. Krige and A. Russo, *A History of the European Space Agency, 1958–1987*, vol. 1, *The Story of ESRO and ELDO, 1958–1973* (Noordwijk, Netherlands: ESA SP-1235, April 2000), chap. 3. See also Michelangelo De Maria and John Krige, "Early European Attempts in Launcher Technology," in *Choosing Big Technologies*, ed. John Krige (Chur, Switzerland: Harwood Academic Publishers, 1993), pp. 109–137.

by the cost, which spiraled to new heights as the expenditures on reinforced concrete silos were factored into the budget. Hence the idea to recycle Blue Streak, stripped of its military characteristics, as the first stage of a multistage civilian satellite launcher, built together with partners in continental Europe. This would save face at home, it would ensure that the money already spent on development was not completely wasted, it would preserve the engineering teams and their skills intact, it would please British industry, and—and this was crucial—it would serve as a gesture of solidarity and good will to the emerging European Common Market, which Britain had previously boycotted, nay, tried to sabotage. Indeed, shortly after the British proposed this joint venture to their continental partners, Prime Minister Harold Macmillan made an official application for his country to join the European Community. Long, drawn-out negotiations ensued before Blue Streak was given a new lease on life. The French would build the second stage atop the British rocket, the Germans would build the third stage, and the Italians would build a test satellite. Clean interfaces were retained to limit technology transfer between firms in different countries to protect competitive advantage and national security (especially in Britain and France, which were both developing independent nuclear deterrents). The ELDO staff had little authority over the separate national authorities and, above all, no power to integrate the three independently built stages of the rocket or to ensure compatibility between the various systems and subsystems built in different countries or in different firms in the same country.[25] By 1966, as many had predicted, ELDO faced the first of many crises that led to its eventual demise in 1972.[26] Development costs had increased from the initial estimate of about $200 million to over $400 million, and no end to the upward spiral was in sight. Blue Streak had been successfully commissioned, while the French and German stages were still under development. What is more, in January 1963, French President de Gaulle had vetoed Britain's application to join the Common Market. For Britain, who was paying almost 39 percent of the ELDO budget, the original technological, industrial, and political rationale for launching the organization had evaporated. In February 1966, her Minister circulated an aide-mémoire to his homologues in the ELDO member states suggesting that it was unlikely that the organization would produce any worthwhile result and that the United Kingdom saw little interest to continue in the program and to contribute financially to it.

This move perturbed the Johnson administration immensely. At the most general level, the U.S. saw ELDO as a technological embodiment of European

25. For a fine description of the failure of management in ELDO, see Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore: Johns Hopkins, 2002), chap. 6.

26. On the crisis, see Krige and Russo, *A History*, vol. 1, chap. 4, sect. 4.3.2.

multilateralism. The withdrawal of the United Kingdom would send a signal that Britain was still not enthusiastic about participating in European integration, which the United States had always regretted. It would also strike a major blow to the gradual movement towards European unity on the continent. This was in a very brittle state at the time. There was a crisis in the European Economic Community (EEC), precipitated by the French, who had begun to boycott the EEC's decision-making machinery so as to liberate the country from its "subordination" to Community institutions and the dilution of sovereignty that that entailed.[27] There was a similar crisis in NATO. The French were not against the Alliance as such but believed that NATO needed reforming. Western European nations were no longer prostrate, as they had been in 1949, and they needed to be prepared to meet a Soviet nuclear threat in Europe with their own independent deterrents (would Washington be prepared to risk New York to defend Paris? it used to be said). "The French have emphasized their dissatisfaction by becoming increasingly an obstructionist force in NATO," one task force wrote, "equating" integration with subordination.[28] In this inauspicious climate, everything possible had to be done to sustain the momentum for European unity. As Under Secretary of State George Ball emphasized, "The United States has a direct interest in the continuation of European integration. It is the most realistic means of achieving European political unity with all that that implies for our relations with Eastern Europe and the Soviet Union . . . and is the precondition for a Europe able to carry its proper share of responsibility for our common defense."[29] While ELDO was not central to European integration, its collapse would provide additional encouragement for those who were increasingly hostile to supranational ventures in Europe.

Saving a European launcher was justified by a second foreign policy concern pressing on the Johnson administration at the time: it would help close the so-called "technological gap" that had opened between the two sides of the Atlantic. Beginning in summer 1965, there were increasingly strident complaints in France, and to some extent Germany, that American business was invading Europe and dominating key sectors of European industry.[30] The U.S. could not

27. Ted Van Dyk to the Vice President, 7 July 1965, folder Germany Erhard Visit [12/65], 12/19–21/65, box 192, National Security Files, Country File Europe and USSR, Germany, LBJ Library.

28. "France and NATO," position paper, 25 September 1965, folder Germany Erhard Visit [12/65] 12/19–21/65, box 192, National Security File, Country File Europe and USSR, Germany, LBJ Library.

29. Department of State to Amembassy Bonn 1209, outgoing telegram, 18 November 1965, signed [George] Ball, folder Germany Erhard Visit [12/65], 12/19–21/65, box 192, National Security File, Country File Europe and USSR, Germany, LBJ Library.

30. SC No. 00666/65B, "US Investments in Europe," CIA Special Report, 16 April 1965, folder Memos [2 of 2], Vol. II, 7/64–7/66, box 163, National Security File, Country File, Europe, LBJ Library. Jean-Jacques Servan-Schreiber's *The American Challenge* (New York: Atheneaum, 1968; translation of *Le Défi américain*) is, of course, the *locus classicus* of this argument.

easily dismiss their concerns. As Frutkin explained, Western Europe's progress in space was "a contribution to the strength of the Free World. An increasing technological gap between us (and them) can only lead to political and economic strains and to weakness."[31] Indeed, the President took this matter so seriously that in November 1966, Johnson personally signed NSAM 357, instructing his science adviser, Donald Hornig, to set up an interdepartmental committee to look into "the increasing concern in Western Europe over possible disparities in advanced technology between the United States and Europe."[32] In its preliminary report, the committee concluded that "the Technological Gap [was] mainly a political and psychological problem" but that it did have "some basis in actual disparities." These included "the demonstrated American superiority in sophisticated electronics, military technology and space systems." Particularly important were "the 'very high technology industries' (particularly computers, space communications, and aircraft) which provide a much greater military capability, are nationally prestigious, and are believed to be far-reaching in their economic, political and social implications."[33] The U.S., Herman Pollack told Sir Solly Zuckerman, Britain's Chief Scientific Adviser, was "seeking new and different ways of expanding cooperation in space because we consider that there is a close connection between [*sic*] technological gap and the development of space technology."[34]

There was a third, even more fundamental argument for supporting the development of a launcher in the ELDO framework. This was, in fact, the single most important reason why Pollock's ad hoc working group of the NASC was asked to look again at the possibilities of sharing booster technology with foreign nations. It also led directly to the release of NSAM 354, expressing American interest in helping ELDO. The argument, in the words of NASA Administrator James Webb, was that enhanced international collaboration in space would be "a means whereby foreign nations might be increasingly involved in space technology and diverted from the technology of nuclear weapons delivery."[35] More precisely, it was by encouraging multilateral

31. Quoted in *Space Business Daily* 25, no. 35 (18 April 1966): 286.

32. NSAM 357, "The Technological Gap," 25 November 1966, available online at *http://www.lbjlib.utexas.edu/johnson/archives.hom/NSAMs/nsam357.gif* (accessed on 9 March 2005). Hornig's official title was the Special Assistant to the President for Science and Technology.

33. "Preliminary Report on the Technological Gap Between U.S. and Europe," attached to David Hornig's letter to the President, 31 January 1967, folder Technological Gap [1 of 2], box 46, Subject File, National Security File, LBJ Library.

34. "Memorandum for the Files. Cooperation with ELDO," 6 May 1966, folder Cooperation in Space—Working Group on Expanded International Cooperation in Space ELDO #1 [2 of 2], box 14, National Security Files, Charles Johnson File, LBJ Library.

35. Webb to Robert McNamara, 28 April 1966, record no. 14459, International Cooperation, International Cooperation and Foreign Countries, folder Miscellaneous Correspondence from CODE I—International Relations 1958–1967, NASA Historical Reference Collection, Washington, DC.

organizations that the nonproliferation of missile technology at the national level could be controlled. A position paper prepared for the very first meeting of Pollack's working group in May 1966 stressed this. Multilateral programs should be encouraged, it asserted, since

> [i]n such a framework rocket programs tend to be more open, serve peaceful uses and are subject to international control and absorb manpower and financial resources that might otherwise be diverted to purely national programs. National rocket programs tend to concentrate on militarily significant solid and storable liquid fueled systems, are less open, and less responsive to international controls. Any break up of ELDO might lead to strengthening national programs tending in the latter direction.[36]

Put differently, since European nations had limited resources to devote to their military and civilian space programs and had to make hard choices about priorities, the U.S. could use the carrot of technological sharing with ELDO to divert human and material resources away from national programs which were more difficult to control and which might see the proliferation of weapons delivery systems.

It was the French national program which particularly bothered the U.S. On 26 November 1965, France had become the third space power by launching its own satellite with its own launcher, Diamant-A, from Hammaguir in Algeria. The feat was repeated in February 1966. This three-stage launcher combined "militarily significant solid and storable liquid fueled systems"—just the kind of technology the U.S. did not want it to develop—in a highly successful vehicle derived from the national missile program.[37] In the light of these achievements and de Gaulle's growing determination to affirm his independence of the EEC and the Atlantic alliance, "The US is concerned that, if ELDO were to be dissolved, France might devote more of its resources to a national, military-related program or that it might establish undesirable bilateral relationships for the construction of satellite launch vehicles"[38]—meaning that unless Britain and America boosted the organization, "the Soviets would

36. T. H. E. Nesbitt, "Meeting No. 1, Committee on Expanded International Cooperation in Space Activities. Subject: Cooperation Involving Launchers and Launching Technology," 17 May 1966, folder Cooperation in Space—Working Group on Expanded International Cooperation in Space. ELDO #1 [2 of 2], box 14, National Security Files, Charles Johnson File, LBJ Library.

37. Diamant-A used a mixture of N_2O_4/UDMH (storable liquid fuels) in its first stage and solid fuel in the second and third stages.

38. "US Cooperation with ELDO," position paper, 21 July 1966, folder Cooperation in Space—Working Group on Expanded International Cooperation in Space. ELDO #1 [2 of 2], box 14, National Security Files, Charles Johnson File, LBJ Library.

move into the vacuum if ELDO collapsed."[39] The U.S. had to contain this threat and to ensure that European institutions emerged "from the present crisis with their prestige, power and potential for building a united Europe as little impaired as possible."[40] Developing advanced space technology in Europe and assisting ELDO to develop its launcher, in particular, were some of the many measures considered by the Johnson administration to achieve that objective in 1966.

THE OBSTACLES TO THE SUPPORT FOR ELDO

Two major obstacles stood in the way of these initiatives. Both were enshrined in National Security Action Memoranda. There was NSAM 294 of 20 April 1964, which dealt with "U.S. Nuclear and Strategic Delivery System Assistance to France." The second was NSAM 338 of 15 September 1965, defining "Policy Concerning U.S. Assistance in the Development of Foreign Communications Satellite Capability."[41]

NSAM 294 stated that since the administration opposed the development of a nuclear force outside the framework of NATO and that since France was doing all it could to evade the constraints of the Alliance, nothing should be done to help its nuclear weapons system (France first successfully tested its A-bomb in the Sahara in February 1960), including the "French national strategic nuclear delivery capability." This included "exchanges of information and technology between the governments, sale of equipment, joint research and development activities, and exchanges between industrial and commercial organizations." This obviously made collaboration with ELDO difficult since how could one be sure that technology that was shared with the organization would not leak through to the French military program?[42]

NSAM 338 was less specific, referring instead to the policy guidelines established by General J. D. O'Connell, the President's Special Assistant for Telecommunications, in a memorandum of 25 August 1965. These guidelines effectively extended the military constraints on the transfer of booster technology to cover specific commercial concerns. O'Connell's memo stipulated

---

39. Anonymous, "Memorandum for the Files, Cooperation with ELDO," meeting with Zuckerman, 6 May 1966, folder Cooperation in Space—Working Group on Expanded International Cooperation in Space. ELDO #1 [2 of 2], box 14, National Security Files, Charles Johnson File, LBJ Library.

40. Department of State to Amembassy Bonn 1209, outgoing telegram, 18 November 1965, signed [George] Ball, folder Germany Erhard Visit [12/65], 12/19–21/65, box 192, National Security File, Country File Europe and USSR, Germany, LBJ Library.

41. NSAM 294, "U.S. Nuclear and Strategic Delivery System Assistance to France," 20 April 1964, and NSAM 338, "Policy Concerning U.S. Assistance in the Development of Foreign Communications Satellite Capability," 15 September 1965, both available online at *http://www.lbjlib.utexas.edu* (accessed 9 March 2005).

42. NSAM 294, "U.S. Nuclear and Strategic Delivery System."

that if the U.S. was to help other countries develop a comsat (communications satellite) capability, it had to have guarantees that the foreign program was integrated into the single global system enshrined in the INTELSAT agreements of 1964. INTELSAT was the international consortium that owned and operated the international comsat system. It had 56 member nations in 1967 (though neither China nor the Soviet Union were members). American interests were represented by COMSAT, a private corporation, 50 percent of whose stock was owned by communications carriers (like AT&T). Voting was weighted according to use, which made it "an unusually attractive international vehicle for the U.S."[43] since it had veto power inside INTELSAT at the time (its voice counted for 54 percent). What is more, the 1964 INTELSAT agreements (due to be renegotiated in 1969 to take account of the expected expansion in the use of comsat technology by other nations) stipulated that the U.S. weight could never drop below 50 percent: "in other words, we control."[44] With this power in its pocket, the "core" of NSAM 338, as McGeorge Bundy explained to LBJ, was "to use our technological superiority to discourage commercial competition with COMSAT and/or wasteful investment in several duplicative Free World defense-related systems" (emphasis in the original).[45] To this end, the U.S. should "withhold provision of assistance to any foreign nation in the field of communications satellites which could significantly promote, stimulate or encourage proliferation of communications satellite systems" outside the INTELSAT framework, *including* "the provision of launching services or launch vehicles for communications satellites."[46]

The significance of NSAM 338 for our story is that it extended the provisions of NSAM 294 beyond national security and foreign policy objectives to protect also U.S. business interests.[47] By defining launchers as a component of the "communications satellite *system*," it included delivery systems inside the

43. Charles Johnson to Walt Rostow, 13 July 1967, folder NSAM 338, box 7, National Security Files, LBJ Library.

44. Ibid.

45. McGeorge Bundy to the President, "Helping Others to Use Communications Satellites," 13 September 1965, folder NSAM 338, box 7, National Security Files, LBJ Library.

46. "Policy Concerning U.S. Assistance in the Development of Foreign Communications Satellite Capabilities," position paper, unsigned, 23 August 1965, folder NSAM 338, box 7, National Security Files, LBJ Library.

47. It should be stressed that NSAM 338 was not restricted to protecting commercial interests, though it included them. As the memo from McGeorge Bundy that I cited earlier makes clear, there were also national security concerns involved. The United States, he noted, would set up a separate national defense comsat system "where security demands" and would encourage "selected allies" (actually Britain and Canada) to "buy time" on this system for their security needs. Otherwise, he wanted everyone to use the single global system for all purposes. The United States thus wanted to discourage the proliferation of regional comsat systems both to limit international competition for a potentially lucrative market and to limit the spread of parallel regional comsat systems for defense (McGeorge Bundy to the President, "Helping Others to Use Communications Satellites").

policies being defended by COMSAT on behalf of the U.S. in INTELSAT. The sale of launch vehicles and launch services *and* technological assistance with the development of an indigenous launch capability were now conditional on the foreign clients' guaranteeing that such launchers would not be used to subvert a single worldwide commercial satellite communications system then under U.S. control. As one senior administrator put it, "It is difficult to maintain international cooperation on this basis."[48]

Finding a Way Around the Obstacles

To overcome these obstacles to technology transfer, NASA and the State Department insisted that to promote U.S. foreign policy and business interests, one had to *distinguish between different types of technology* and *the specific foreign policy options* that America wanted to promote. They were convinced that American leadership, and its ability to restrict the proliferation of weapons systems and comsats, was best achieved by treating technology transfer on a case-by-case basis and by "building high walls around small fields," as it is sometimes called today, rather than by blanket restrictions which treated both technology and foreign policy as seamless wholes.

To achieve this, a number of crucial distinctions had to be made. Current U.S. policy was dominated by the "dual-use" aspect of boosters as both ballistic missiles and as stages of satellite launchers. This was too simple, Webb pointed out: "If we could focus our controls on the weapons themselves, we might even hope to free vehicle technology for maximum stimulus of space activity abroad."[49] Consider the constraints on booster technology imposed by NSAM 294. As Webb pointed out to Defense Secretary McNamara, although high-energy, cryogenic, or nonstorable upper stages might conceivably be employed for military purposes, in practice they would probably not be deployed in that way. "Even in the case of France," Webb stressed, "it seems likely that encouragement to proceed with upper stage hydrogen/oxygen systems now under development might divert money and people from a nuclear delivery program rather than contribute to that which is already under way using quite different technology."[50] Guidance and control technology was another gray area. An American company had recently been refused a license to assist France with

48. Charles Johnson to Walt Rostow, 13 July 1967.

49. Webb to Johnson, 26 April 1966, record no. 14459, International Cooperation and Foreign Countries, folder Miscellaneous Correspondence from CODE I—International Relations 1958–1967, International Cooperation, NASA Historical Reference Collection, Washington, DC.

50. Webb to McNamara, 28 April 1966, and reply, Bob [McNamara] to Jim [Webb], 14 May 1966, record no. 14459, International Cooperation and Foreign Countries, International Cooperation, folder Miscellaneous Correspondence from CODE I—International Relations 1958–1967, NASA Historical Reference Collection, Washington, DC.

the development of gyro technology. But as Richard Barnes, the Director of Frutkin's Cooperative Projects Division, pointed out to the chair of the NSAM 294 review group, gyros of comparable weight and performance were already available in France. The release of inertial guidance technology to Germany had been officially sanctioned in July 1964 on condition that it was not employed "for ballistic missile use or development."[51] And, as we mentioned earlier, a strapped-down "guidance" package used on the Scout launcher had already been exported to Japan. Here, and in general, wrote Webb to McNamara, rather than a blanket restriction, "we might be better off were we to concentrate on a few very essential restrictions, such as *advanced* guidance and reentry systems" (my emphasis). In a supportive reply to Jim, Bob reassured the NASA Administrator that he strongly supported international cooperation in space and that he had directed his Department of Defense staff "to be as liberal as possible regarding the release of space technology for payloads and other support items."[52]

One important consideration shaping the argument for a revision in policy was that restrictions on the export of some items were now redundant since European booster technology was advancing rapidly without external help. It was also counterproductive to deny a nation a technology if it could easily and quickly be obtained from a source other than the United States: this would not simply be to the detriment of American business, but also to U.S. foreign policy, particularly if that source was the Soviet Union. Thus Barnes suggested (and Webb concurred) that the interpretation of NSAM 294 on the export of booster technology needed to be more specific. The guidelines should deny to a foreign power "<u>only</u> those <u>few</u> <u>critical</u> items which are clearly intended for use in a national program, would significantly and directly benefit that program in terms of time and quality or cost, and are unavailable in comparable substitute form elsewhere than the US" (emphasis in the original). The guidelines should also explicitly recognize that it was in America's interest to promote European space collaboration, so that technology transfer intended for multinational programs like ELDO (and ESRO—the European Space Research Organisation) would "normally be approved" so long as the items were "of only marginal benefit to the national program" or "were available elsewhere than the US without undue difficulty or delay."[53] In short, requests for technology transfer were to be treated on a case-by-case basis and should take into account the kind of technology at issue, its likely uses in practice, the global state of the market for the technology,

51. NSAM 312, "National Policy on Release of Inertial Guidance Technology to Germany," 10 July 1964, available online at *http://www.lbjlib.utexas.edu* (accessed 9 March 2005).

52. Webb to McNamara, 28 April 1966, and reply, Bob [McNamara] to Jim [Webb], 14 May 1966.

53. Richard Barnes to Scott George, Chairman, NSAM 294 Review Group, Department of State, 15 April 1966, record no. 14459, International Cooperation and Foreign Countries, International Cooperation, folder Miscellaneous Correspondence from CODE I—International Relations 1958–1967, NASA Historical Reference Collection, Washington, DC.

and the importance of collaboration from a foreign policy perspective. The last, along with U.S. business interests, was not to be sacrificed on the altar of an overcautious, generalized reluctance to share technology just because it *might* encourage programs which sections of the U.S. administration disapproved of.

Frutkin was also keen to relax the constraints on the sharing of comsat technology that were embodied in NSAM 338. Europeans, he wrote, were persuaded that the United States was "seeking by all means, fair or foul, to maintain political and technical control of Intelsat."[54] He was convinced that, to allay their suspicions, the U.S. had to be prepared to provide launch services on a reimbursable basis for (experimental) foreign communication satellites. This would "extend the market for American vehicles, remove some incentive for independent foreign development of boosters, and assure that we could continue to exercise critical leverage in foreign comsat activities rather than lose such leverage." Frutkin also favored the removal of restrictions on the export of satellite technology as such, including the kick-stage and propulsion technology needed to place a communications satellite in geosynchronous orbit.

An anonymous internal memorandum argued that technological sharing was the best way to enroll foreign firms and their governments in American comsat policy. By allowing "United States firms to enter cooperative arrangements with the communications and electronics manufacturing industry in other countries," notably in Western Europe, industries in these countries would develop the technical know-how needed for them "to compete effectively for contracts for the space segment of the global communications system." This would "remove a current irritant, primarily expressed by the French but also shared by the British, Italians and Germans, about their inability to supply hardware for the INTELSAT space segment." And even if such technological sharing did not irreversibly lock these European countries into the single global system favored by the U.S., one could expect them to have a "greater incentive" to collaborate with America in developing that global system. One might also expect them to be more cooperative and sympathetic to the U.S. position during the renegotiation of the INTELSAT agreements scheduled for 1969. Anyway, if the U.S. did nothing to help these nations, they would eventually develop the technology on their own, without American help, and would be quite capable of establishing separate, regional communications satellite systems in due course.[55] As Frutkin explained, "(a) We do need to

54. A. W. Frutkin to Mr. Hilburn, "Memorandum for Mr. Hilburn—AAD, Policies Relevant to '69 Revision of Intelsat Agreement," 11 April 1966, record no. 14459, International Cooperation and Foreign Countries, International Cooperation, folder Miscellaneous Correspondence from CODE I—International Relations 1958–1967, NASA Historical Reference Collection, Washington, DC.

55. "Communications Satellite Technology," undated and unsigned memorandum, but obviously written around April 1966, folder Cooperation in Space—Working Group on Expanded International Cooperation in Space, ELDO #1 [2 of 2], box 14, National Security Files, Charles Johnson Files, LBJ Library.

improve our situation in Intelsat with specific reference to the 1969 negotiations. (b) We already have a strong technical lead in the comsat field. (c) We already have an adequate voting majority in Intelsat. (d) We can rely upon our technical, moral and financial strength to assure continuing leadership—without seeking to deny technology to our partners in Intelsat."[56] Rather, then, use technological sharing as an instrument to divert foreign firms and governments into working with U.S. industry within the framework of a single global system where the U.S. was the dominant partner than have them defiantly develop an independent national or regional comsat capability over which the U.S. had no control and which could be used to bargain for a major revision of the INTELSAT agreements against U.S. interests.

I have stressed the pressure which foreign policy concerns played in arguing for technological sharing with ELDO. Implicit in my account is another dimension of the issue: the need to promote and channel the interests of American industry. Indeed, NASA officials like Frutkin mediated between firms who wanted to export technology abroad and the Office of Munitions Control in the State Department, which authorized them to do so. As Frutkin explained to Margrave, who directed the Office, American firms were putting NASA, the Department of Defense, and the State Department under extreme pressure to export nonmilitary vehicle technology to individual national firms in Europe.[57] By releasing export controls on the transfer of this technology to ELDO, one could at once satisfy their demands and divert them from the national to the multilateral level in line with U.S. foreign policy. We see, then, that arguments for relaxing constraints on booster technology were intended not simply to advance multinationalism in Europe and to help ELDO, but also to satisfy pressure for access to the launcher construction market from U.S. business. This stakeholder in international space collaboration is almost always ignored; it should not be.

Denouement

Those administrators who were for, and those were against, relaxing constraints on technology transfer to ELDO shared a concern for nonproliferation. They differed on how best to achieve this. NASA and the State Department argued that by sharing high-energy nonstorable liquid-fuel launcher technology with ELDO, they could divert resources away from national military programs for which such fuels were obsolete. Similarly, they argued that by letting U.S. firms help European industry to build up its comsat capability,

56. Frutkin to Hilburn, "Memorandum for Mr. Hilburn."

57. Frutkin to Margrave, 1 April 1965, record no. 14465, International Cooperation and Foreign Countries, International Cooperation, folder International Policy Manual Material from Code I, NASA Historical Reference Collection, Washington, DC.

they could more easily engage European governments in the single global system promoted and controlled by Washington at the expense of a proliferation of competing regional communications satellite systems which could serve independent commercial and military needs. The defenders of NSAM 338 were adamant, however, that the U.S. should do nothing to help other countries develop comsats, or the powerful launchers needed to place them in geostationary orbit, without cast-iron guarantees that these would only be used in the INTELSAT framework. For them, technological assistance in either of these domains could only hasten proliferation, not contain it. By summer 1967, it was clear that the latter had won the day.

The reasons for this are complex and will be dealt with very briefly here. Developments in Europe played a role. ELDO (temporarily) survived its crisis and, by September 1966, had reoriented its program unambiguously in favor of developing a launcher called Europa II that achieved geostationary capability by adding a fourth, French-built solid-fuel stage to the previous ELDO-A rocket. In parallel, France and Germany decided to fuse their national comsat projects in a joint experimental telecommunications satellite called Symphonie to be launched by Europa II from the new French base in Guyana.[58] ELDO had moved from an artificial political construct to an organization with a well-defined technical mission and was far less vulnerable to offers of American help.

From the American point of view, to channel this "European fixation on comsats and launch vehicles," as Richard Barnes put it, the U.S. had to make an unambiguous offer for technological assistance in domains which satisfied the interests of both parties.[59] With cryogenic fuels no longer being considered and with France responsible for the kick-stage into geostationary orbit, this was going to be *very* difficult. Divisions within the administration on how best to interpret the requirements of NSAM 338 made it virtually impossible. Frutkin described the state of play in August 1966 to Webb, just before the NASA Administrator was to leave on a crucial European tour to discuss possible collaborative projects. While the "general atmosphere for space cooperation with the United States may have improved slightly," thanks to the initiatives by NASA and the State Department which we have described in this paper, they had done little more than "clear the air somewhat." The Europeans, Frutkin told Webb, "know of no progress in easing US restrictions upon communications satellite technology," and "it may be sometime" before the progress that had been made in Washington could be divulged to them. Webb was therefore to repeat the standard answer to the usual request for comsat launch assistance: "that we could certainly give consideration to such a proposition on the assumption that

58. The official agreement between the two governments was signed on 6 June 1967.

59. RJHB to AWF, "The 'Webb Commission,'" 5 May 1967, record no. 14459, International Cooperation and Foreign Countries, International Cooperation, folder Miscellaneous Correspondence from CODE I—International Relations 1958–1967, NASA Historical Reference Collection, Washington, DC.

the European countries take their INTELSAT commitment to a single global system as seriously as we do."[60] By virtue of this approach, there was, to quote Barnes again, a "deterioration of 'climate for cooperation' caused by (1) US policies and actions within the Intelsat, and (2) US export policies in support of the 'single global system.'" This led to "European reaction of suspicion and distrust to US offer to escalate cooperation."[61]

As Barnes remarked, the breakdown in trust between the two sides of the Atlantic was fueled by a very public, high-level offer to "escalate" space collaboration with West Germany and other European allies, which had gained momentum throughout 1966.[62] In an exchange of toasts between President Johnson and Chancellor Ludwig Erhard at a state banquet on 20 December 1965, LBJ suggested that existing scientific cooperation should be extended to embrace "an even more ambitious plan to permit us to do together what we cannot do alone." The President gave two examples of "demanding" and "quite complex" collaborative projects which would "contribute vastly to our mutual knowledge and to our mutual skills": a solar probe and a Jupiter probe. He also announced that NASA Administrator Webb would be traveling to Europe shortly to discuss these ideas in Germany and with other European governments.[63]

The target and timing of Johnson's offer were not coincidental. Erhard was a convinced and reliable American ally and was deeply hostile to de Gaulle's attempts to undermine the existing structures of both NATO and the EEC. As Secretary of State Dean Rusk stressed to James Webb, with the Chancellor boldly resisting this attack on European institutions, "it [was] politically important for the United States to cooperate as closely as possible with Germany." Increasing "the vigor and scope of space cooperation" with the country would be tangible, "positive evidence of constructive American interest in Germany," and it would encourage Erhard to take the lead in advancing U.S. policies in the region.[64]

The fanfare surrounding this offer for expanded scientific cooperation contrasts sharply with the reluctance to disclose publicly the possibility for technological collaboration with ELDO. And it was counterproductive in many respects. The American attempt to isolate de Gaulle was evident for all to see; indeed, Erhard was forced to relinquish his post in November 1966, accused of

60. Frutkin to Webb, "Memorandum for Mr. Webb," 11 August 1966, record no. 14618, folder Germany (West), 1956–1990, Foreign Countries, International Cooperation and Foreign Countries, NASA Historical Reference Collection, Washington, DC.

61. RJHB to AWF, "The 'Webb Commission.'"

62. This initiative is worthy of a separate paper; I give only the barest outline here.

63. "Exchange of Toasts Between President Lyndon B. Johnson and Chancellor Ludwig Erhard of the Federal Republic of Germany (In the State Dining Room)," 20 December 1965, folder Germany Erhard Visit [12/65], 12/19–21/65, box 192, National Security Files, Country File Europe and the USSR, Germany, LBJ Library.

64. Dean Rusk to James Webb, 29 August 1966, record no. 14618, folder Germany (West), Foreign Countries, International Cooperation and Foreign Countries, NASA Historical Reference Collection, Washington, DC.

mismanaging the economy and of being too pro-American and anti-French. The cost of the kind of projects discussed (about $100 million) was deemed to be excessive, given the resources available for space science and European priorities (although eventually Germany did embark on a bilateral venture with the U.S., the $100-million Helios project to send two major spacecraft within 45 million miles of the Sun).[65] Finally, with the U.S. publicly insisting on the need to respect the INTELSAT agreements, the American offer was also interpreted by some as a strategy to divert scarce European resources into science and away from applications, notably telecommunications. "All in all," wrote Frutkin to Webb in August 1966, "we must say the President's proposal got off to a poor start due to misunderstandings which are inevitable when a proposition of this sort is made in the headlines without preparation of the ground."[66] Barnes put it pithily: because of European "suspicion and distrust," aggravated by President Johnson's spectacular overtures to Chancellor Erhard, there was "no prospect for escalating cooperation with Europe unless (1) US is willing to modify its present export control policies, and (2) we could offer other possibilities for cooperation in areas of interest to them (i.e., comsats and vehicles)."[67] This was not to be.

CONCLUSION

The defeat of those inside NASA and the State Department who considered sharing communications satellite and booster technology with Europe in mid-1960s was simply the first of a series of setbacks for those in the administration who believed that technological sharing could be used to unite Europeans around projects which were at once useful to them and compatible with the maintenance of U.S. leadership in strategic areas. Indeed, the battle was repeated just a few years later with the same result. European hopes to be integrally engaged at the technological level in the post-Apollo program, sparked by NASA Administrator Tom Paine in the late 1960s, were soon dashed. The compromise that ensued left Germany taking the lead in building a shirtsleeve-environment scientific laboratory that could fit in the Space Shuttle's cargo bay and that, crucially, preserved the basic principles of clean interfaces and no exchange of funds more or less intact. Indeed, Europe's ongoing struggle to be a genuine partner at the level of technological and managerial sharing with NASA and the U.S. might suggest that, when the chips are down, the need by powerful forces in the U.S. to protect national industry and national security will always prevail over foreign policy considerations. For them, American leadership is best preserved by denying sensitive technology, not by finding ways to use technological sharing to orient a partner's program in line with U.S. interests.

65. The project is discussed in Frutkin, "International Cooperation in Space."

66. Frutkin, "Memorandum for Mr. Webb."

67. RJHB to AWF, "The 'Webb Commission.'"

The negotiations over the ISS, particularly with Russia, show that this is not always so.[68] Indeed, it is striking that here, NASA *has* departed from past practice in accepting critical-path contributions from Canada and Italy and, more significantly, in accepting that there be a joint U.S.-Russian core and infrastructure as the foundation of the program. Sadeh has enumerated the foreign policy motivations for this move. Some were purely symbolic, e.g., to signal an end to the Cold War and Russia's entry into the club of advanced Western industrial states. Others were fully in line with the use of technology as an instrument of foreign policy as we have described it here. In particular, in these negotiations, as in the debates over the help to ELDO 30 years earlier, technological sharing was an instrument to steer Russia's civilian and military high-tech sectors along paths in line with American interests. Thus, integrating Russia into the core of the Space Station "enhances U.S. efforts to strengthen Russia's commitment to adhere to guidelines of international non-proliferation standards regarding ballistic missiles and nuclear technology, lends support to U.S. efforts to privatize and demilitarize the high-technology sector in Russia . . . and encourages Russian scientists and engineers to work on 'peaceful' projects rather than selling their talents to other, possibly hostile, states."[69] It also, of course, diverts scarce Russian resources away from projects of which the U.S. might not approve. In short, the *kinds of* arguments for technological sharing with ELDO in 1966 were still being used when dealing with Russia in 1996. The difference is that ELDO had nothing to offer at the technical level, while Russia could use its extensive experience in human spaceflight as a bargaining chip to win some key concessions. The lesson is clear: if we want to make sense of international collaboration in space from a U.S. perspective, we need focus carefully not only on what technology the U.S. has to offer, but what its potential partner has to give. In any event, as I have stressed, we simply cannot grasp the dynamics of international cooperation in space if we do not situate the scientific and technological *content* of the collaborative venture at the core of our analysis and relate it to strategies to maintain American "leadership" and some measure of control over the space programs of her partners.

I should like to thank Roger Launius for helpful comments on a previous draft of this paper.

---

68. Two important studies of policy regarding the Space Station are John M. Logsdon's *Together in Orbit: The Origins of International Participation in the Space Station* (Washington, DC: Monographs in Aerospace History, No. 11, November 1998) and Howard E. McCurdy's *The Space Station Decision: Incremental Politics and Technological Choice* (Baltimore: Johns Hopkins, 1990).

69. Eligar Sadeh, "Technical, Organizational, and Political Dynamics of the International Space Station Program," *Space Policy* 20, no. 3 (August 2004): 171–188. Sadeh makes no systematic distinction between the dimensions of the collaboration which were, indeed, symbolic and the far more substantive, material items that I have quoted here. Indeed, quite mistakenly in my view, he reduces *all* these policy considerations to the symbolic level. This evades the question of how the United States uses technology to steer the space and high-tech programs of its partners in particular directions.