The Cold War, RAND, and the Generation of Knowledge, 1946-1962

David Hounshell

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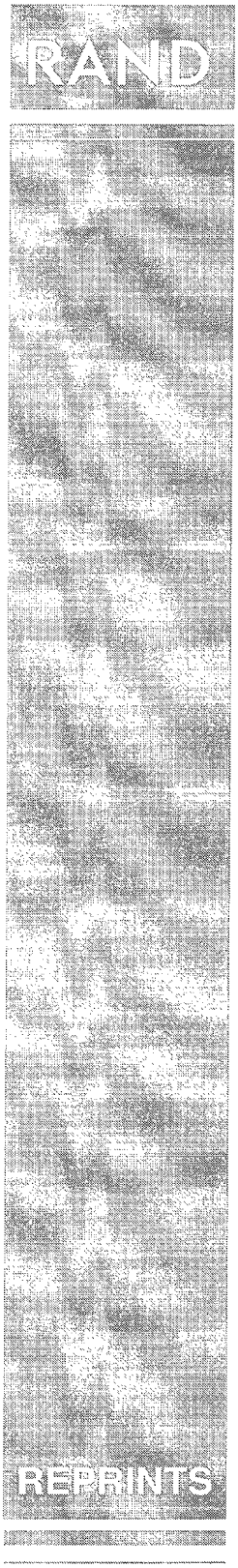

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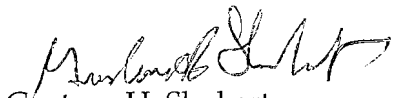
The article reprinted here was researched and written by Professor David Hounshell of Carnegie Mellon University as part of his work on the *RAND History Project*.

The substance of this article, which focuses on some of RAND's early technological innovations, should be of special interest to scholars, researchers, and students of science and technology as well as those curious about RAND and its history.



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DAVID HOUNSHELL*

The Cold War, RAND, and the generation of knowledge, 1946–1962

THE DRAMATIC BREACHING of the Berlin Wall in November 1989 signalled to millions of observers throughout the world that the tense, forty-five year long Cold War was ending—a development confirmed with the bloodless self-destruction of the Soviet Union in December 1991. The conclusion of what President John F. Kennedy called the "long twilight struggle" promised to end decades of ideological conflict, unprecedented arms competition, and massive expenditures for national defense on both sides of the "Iron Curtain." The Cold War had profoundly altered the course of national development in both the United States and the Soviet Union as vast sums were expended to create national security complexes that insinuated themselves into virtually every corner of American and Soviet societies with profound behavioral and psychological consequences. This was especially true in the realms of science and technology where the pursuit of knowledge became increasingly an instrument for ensuring national security. At no time in human history had such abundant resources been devoted to scientific and technological research and development, albeit in the pursuit of largely military interests.

Now, more than half a decade after Boris Yeltsin took charge of the Russian republic, large segments of the scientific and technical communities in the United States are scrambling to protect programs and institutions created during the Cold War but whose missions and purposes are no longer clear. Congressional committees have debated closing national laboratories, terminating long-standing defense research contracts, and reordering the federal science and technology complex. At the same time, the defense industry—long a locus of intense scientific and technological activity—is rapidly contracting, with numerous mergers and massive layoffs of engineers and scientists. Also, universities that benefitted enormously

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from the "social contract" that emerged early in the Cold War are bracing for severe contractions in research funding and scrambling to secure their viability.

Recently a group of leading scholars of the social studies of science, technology, and democracy during the Cold War met to explore the needs and opportunities for research. A consensus emerged that although scholars had begun to identify some of the broad contours of Cold War processes, vital issues and rich veins of documentation remained virtually untouched.[1] Among the issues identified for further study were the evolution of science and technology policy during the Cold War, the effects of the Cold War on the nature and prosecution of knowledge production in both the Soviet Union and the United States, the ways in which the Cold War altered existing institutions and spawned entirely new ones, the implications of the Cold War for U.S. and Soviet economic development, and the relationship between the intensive concentration of national resources on science and technology and concomitant cultural shifts.

Debate has already opened over the extent to which massive government—largely military—sponsorship of scientific research and development distorted the trajectory of American and Soviet science. Paul Forman's bold, impassioned article of 1985,"Behind quantum electronics: National security as basis for physical research in the United States, 1940–1960," set the initial terms of the debate.[2] Forman argued that massive funding of physics and electronics research by the United States government for national security purposes not only influenced the institutions that undertook this research, but also unmistakably altered the content and nature of quantum electronics research. Stuart W. Leslie pushed Forman's thesis further and crystallized the debate.[3] Reviews of Leslie's *The Cold War and American science* by Roger Geiger and Daniel Kevles contested Forman's "distortionist" critique of Cold War science policy.[4] Kevles and

1. "Science, technology, and democracy in the Cold War and after: A strategic plan for research in science and technology studies," a report prepared for the National Science Foundation, 1995. Available from NSF's Program in Science and Technology Studies.

2. Paul Forman, "Behind quantum electronics: National security as basis for physical research in the United States, 1940–1960," *HSPS, 18:1* (1985), 149–229.

3. Stuart W. Leslie, *The Cold War and American science: The military-industrial-academic complex at M.I.T. and Stanford* (New York, 1993). Also, for an application of the Forman thesis to the development of the social sciences at Stanford University, see Rebecca Sue Lowen, "Exploiting a wonderful opportunity: Stanford University, industry and the federal government," (Ph.D. diss., Stanford University, 1990).

4. Roger Geiger, review of *The Cold War and American science* by Stuart W. Leslie, *Technology and culture, 35:3* (1994), 629–631; and Daniel J. Kevles, "R&D powerhouses," review of *The Cold War and American science* by Stuart W. Leslie, *Science, 260:5111* (May 21, 1993), 1161–1163. For Kevles' earlier thoughts on this topic, see Daniel J. Kevles, "Cold War and hot physics: Science, security, and the American state, 1945–1956," *HSPS, 20:2* (1990), 239–264.

Geiger maintained that although Leslie had shown how both the Massachusetts Institute of Technology (MIT) and Stanford University had grown rapidly owing to research support during the Cold War, he had failed to demonstrate how the funding had led to the deviation of scientific research from its supposed "true" or "natural" path. Instead of distorting the course of scientific inquiry, Leslie's critics argue, research for national security generously supplemented pre-existing trajectories.

The distortionist hypothesis in science has a long-standing corollary in technology, business, and economics: "crowding out." First put forward by such scholars as Seymour Melman, "crowding out" alludes to the notion that in an environment of necessarily scarce resources, massive spending on national defense prohibits, or crowds out, a certain amount of investment in peaceful commercial research and development.[5] Melman and his supporters argue that American manufacturers were lured by the attractiveness of non-competitive military markets away from participation in competitive, civilian markets and became dependent on government contracts for survival. Although this strategy increased short-term profits, it came at the expense of the nation's leadership in an increasingly globalizing economy where low-cost, high-quality manufacturing for civilian markets was the rule of order. Globalization of commercial manufacturing by nations such as Japan and Germany thus overtook the "permanent war economy" of the United States. "The military-industrial complex," about which President Eisenhower voiced concern in his farewell speech in 1961 as being too powerful for a democratic nation, ironically served to undermine the economic power of the U.S. and lower Americans' standard of living. As with the distortionist critique, the crowding-out argument has been countered by scholars who argue that the United States gained its technological leadership because of national-security policies and that it remains in a position of scientific and technological leadership for the very same reason.[6]

This paper contributes to the discourse about science and technology during the Cold War by examining the history and output of a research

5. See Seymour Melman's *The defense economy: Conversion of industries and occupations to civilian needs* (New York, 1970); *Our depleted society* (New York, 1965); *Pentagon capitalism: The political economy of war* (New York, 1971); and *The permanent war economy: American capitalism in decline* (New York, 1974).

6. Relevant critiques of the crowding out hypothesis are fewer in number than are the works promoting the idea. One of the foremost critics of the crowding out hypothesis is George Gilder, *Microcosm* (New York, 1989). For a broad discussion of the debate, see Otis T. Graham, *Losing time: The industrial policy debate* (Cambridge, MA, 1992) and Richard J. Samuels, *Rich nation, strong army* (Ithaca, 1994).

institution created at the time. Established in 1948 as an independent nonprofit research and development organization and funded largely by the United States Air Force up to 1962, the RAND Corporation can be said to be an almost "pure Cold War" institution. After setting forth RAND's early history (Section 1), I shall give summaries of its major programs (Section 2) and an indication of its wider influence (Section 3).

1. FOUNDATIONS AND EARLY HISTORY

Acquiring its name out of the acronym from Research ANd Development, RAND is the pioneering and probably the most successful of what came to be known as "think tanks"—"a curious phrase," as James Allen Smith writes, "suggesting both the rarified isolation of those who think about policy, as well as their prominent public display, like some rare species of fish or reptile confined behind the glass of an aquarium or zoo."[7] In the post-World War II period, driven in large part because of the very success of the RAND Corporation, think tanks began to influence the formulation of policy, initially in matters of national security and eventually in issues of social and economic policy. As Smith stresses,[8]

> In fact RAND and *think tank* are virtually synonymous....RAND became the prototype for a method of organizing and financing research, development, and technical evaluation that would be done at the behest of government agencies, but carried out by privately run nonprofit research centers....The RAND model flourished in the 1950s, spinning off competitors and causing the other military branches to set up similar units. Such groups as the Mitre Corporation, the Systems Development Corporation, Analytic Services, the Center for Naval Analyses, the Research Analysis Corporation, and the Institute for Defense Analyses have given military planners routine and sustained access to researchers with advanced scientific and technical skills.

Although RAND spawned several competitive think tanks and inspired the creation of others, not only in defense research but also in social policy, none of its imitators can match its achievements in the production and

7. James Allen Smith, *The idea brokers: Think tanks and the rise of the new policy elite* (New York, 1991), xiv. Smith's book is an excellent overview of think tanks and their role in policy formulation in post-World War II America. His interpretation of RAND is based to a large degree on the works, cited in notes below, by Bruce Smith, Fred Kaplan, and Gregg Herken. These works—and consequently Smith's book—interpret RAND largely through the history of its famous basing study led by Albert H. Wohlstetter. Although this study was highly influential in RAND's success during the 1950s, its history conveys only a tiny fraction of RAND's work—something comparable to describing an elephant based only on knowledge of its tail. Some have said the acronym RAND stands for Research And No Development.

8. Ibid., 115–116.

distribution of new knowledge, its impact on the entire domain of the social sciences and many areas of the "harder" sciences, and its influence in the arena of policy formulation. The reasons for these achievements surely reside with the timing of its creation, the manner and context in which it was created, and the ethos of independent research that quickly developed there. Without understanding what made RAND tick, the nature of its knowledge production, and its influence not only in knowledge production but also in policy formulation, no historian can fully understand research and development in Cold War America.

RAND was the brainchild of General Henry H. "Hap" Arnold, the commanding officer of the Army Air Forces during World War II. Believing that scientific and technical research had played a key role in the development of U.S. air power, Arnold wrote the Secretary of War,[9]

> During this war the Army, Army Air Forces, and the Navy have made unprecedented use of scientific and industrial resources. The conclusion is inescapable that we have not yet established the balance necessary to insure the continuance of teamwork among the military, other government agencies, industry, and the universities. Scientific planning must be [done] years in advance of the actual research and development work.

In Arnold's mind, RAND was to be the Air Force's agent for such "scientific planning." In October 1945 Arnold met with MIT researcher Edward Bowles, a consultant to the Army Air Forces who had run an operations research unit during the war; Donald Douglas, president of Douglas Aircraft Company; Arthur Raymond, Douglas's chief engineer; and Franklin Collbohm, an engineer from Douglas who had worked with Bowles and Raymond in applying newly developed operations research methods to optimize the Army Air Force's B-29 bombardment campaigns, to plan what became Project RAND. By March 1946, the enterprise was operating as a separate division of Douglas Aircraft under a contract with the Army Air Forces (reporting to the Deputy Chief of the newly organized Air Staff for Research and Development). The contract stated that "Project RAND is a continuing program of scientific study and research...established to provide the Air Force with independent objective analyses."[10] In less than two years, the organization included more that two hundred professionals trained in mathematics, engineering, aerodynamics, physics, chemistry, economics, psychology, and other disciplines, who engaged

9. Quoted in *40th year: The RAND Corporation* (Santa Monica, CA, 1989), 3.

10. Quoted in Albert Wohlstetter, "RAND's continuing program of broad policy study: Problems and incentives," 22 Feb 1960, attached to Wohlstetter to Management Committee, M-953, 22 Feb 1960, Robert Specht Papers, RAND Corporation Archives, Santa Monica, California.

primarily in interdisciplinary research on such problems as how to launch and orbit an artificial satellite around the earth, the use of atomic fission for airplane propulsion, maximizing performance of conventional aircraft, development of titanium and other advanced materials, and damage effects of nuclear bombs.

By 1948, however, managers at Douglas Aircraft had concluded that Project RAND posed problems for the company's efforts to obtain aircraft procurement contracts with the Air Force because of the apparent conflict of interest represented by the Air Force's Douglas-based "think tank," with its privileged relationship with and influence on the Air Force. RAND's own managers and researchers also felt increasingly uncomfortable in the product-oriented culture of Douglas. Consequently, in May 1948, RAND was established as a free-standing, private, non-profit research organization. Backed by a large interest-free loan from the Ford Foundation and the foundation's pledge of credit security to commercial lenders, RAND quickly found itself in a position to construct its own building in Santa Monica, California, and to continue its mission—that of "mobiliz[ing] certain engineering and scientific skills to assist [the Army Air Force] in arriving at sound conclusions fundamental to the development of [its] programs."[11]

From its earliest days, RAND developed an organizational culture that prized intellectual curiosity and independence. This independence no doubt stemmed from the immediate postwar environment in which scientists, engineers, and mathematicians leveraged their wartime successes to assert the wisdom of abundant, unfettered research. The image that appears again and again in RAND's self-characterizations during its first fifteen years is "a university without students." That is, the organization and its researchers were committed to the generation of new knowledge—what Vannevar Bush had termed "basic research" in his science policy recommendations to the President, the famous report of 1945 entitled *Science, the endless frontier*.[12] The frontier for RAND was of a dual character. On the one hand, there was the methodological frontier, in which RAND's researchers pioneered. On the other hand, the emerging Cold War itself constituted a frontier, for it opened up a vast set of problems and opportunities at stakes higher than those for which the forty-niners or boomer sooners had played.

11. Arthur E. Raymond, "Talking outline—RAND briefing of [the Army Air Forces] 4–21–47," as quoted in David R. Jardini, "Out of the blue yonder: The RAND Corporation's diversification into social welfare research, 1946–1968" (Ph.D. diss., Carnegie Mellon University, 1996), 28. RAND's decision to build its own building unquestionably lent solidity and permanence to the nascent organization.

12. Vannevar Bush, *Science, the endless frontier: A report to the President on a program for postwar scientific research* (Washington, D.C., 1945).

For many RAND researchers, RAND's mission was nothing short of the salvation of the human race. The more fervent RAND's researchers grew about saving the world, the more fiercely independent they became.

During the 1950s and early 1960s, the Air Force became highly dependent upon RAND. When Congress brought heavy pressure on the Air Force during the early 1960s to cut back on defense consultants, the Secretary of the Air Force, Eugene Zuckert, sought genuinely to comply by trying to rein in RAND. That did not work. Frank Collbohm, RAND's president, informed Zuckert that "the only alternative to [the Air Force's] giving RAND what it wants is to close down the RAND operations [immediately]....[N]o compromise was in the cards."[13] RAND's value to the Air Force, in spite of RAND's sometimes-annoying, fierce independence, can be judged by the report that Max Golden, Zuckert's deputy, conveyed to his boss about a meeting in which he tried to reach a compromise with Collbohm:[14]

> After listening to his line for over an hour, I told Mr. Collbohm that (a) his dedication and that of his colleagues overwhelmed me, (b) unlike RAND we could not afford the callous luxury of jeopardizing the national interest, and (c) accordingly, with a gun at our head, I was authorized to go along with the terms of the old negotiation [i.e., status quo ante].

Only through independent research, RAND's management and researchers believed, could RAND adequately address the problems of the Air Force in the context of the Cold War struggle with the Soviet Union.

Following its creation in 1948 as an independent, non-profit research organization, RAND pursued numerous approaches to solving real and potential problems confronted by the Air Force as the service's leaders sought to build both a powerful institution within the new Department of Defense and an invulnerable air strike capability against the Soviet Union. The core of RAND's work, however, was systems analysis. John D. Williams, the brilliant and inspirational head of its Mathematics Department, perhaps put it best:[15]

> The thesis that the art of war is, at least in part, amenable to scientific handling derives support from the success which attended certain applications of scientific method during World War II—to tactical, strategic, and development problems. These successes with small, isolated components of the theory of warfare suggest the possibility of similarly treating the entire subject, and justify RAND in approaching it.

13. Max Golden, "Memorandum for Mr. Zuckert," 28 Apr 1962, General Curtis LeMay Papers, Box B-127, Library of Congress, Washington, D.C.

14. Ibid.

15. J.D. Williams to F.R. Collbohm, D-7, 1947, as quoted in Jardini (ref. 11), 33.

RAND sought to build a "science of warfare," whereby the overall performance of the Air Force could be optimized. "Systems analysis" became the means by which the organization sought to realize this goal.

The starting points for this new systems analysis were the methods developed during the war by applied mathematicians in Britain and the United States (operations research) and by engineers at Douglas (alternative technical systems ranking charts). But as those who employed these methods during the war well knew, these seemingly powerful new methods depended upon static analysis; they could not handle dynamic changes within the systems they sought to optimize. Consequently, RAND's researchers aggressively pursued the development of new, computer-programmable analytical methods that could handle changes in initial conditions; hence RAND's development of enormously important analytical tools such as linear and dynamic programming, systems simulation, game theory, and artificial intelligence.[16] These methods, in turn, gave RAND's proponents of systems analysis all the more reason to believe they could perfect systems analysis as the complete science of warfare. This science of warfare would also incorporate important new social science research methods and findings, some of which derived exclusively from the Cold War context of defending the nation from the Soviet Union. These included a broad range of Soviet studies, including calculations of Soviet economic output and prices, war-making capabilities, and decision-making processes.

Expectations at RAND for the development of systems analysis ran very high, yet again and again its researchers confronted what came to be known as the "specification problem": exactly what was being optimized (maximized or minimized)?; what should be optimized?; how could one be certain that optimization was possible given conditions of extreme uncertainty in very large, highly dynamic systems such as global nuclear warfare?

RAND's first, large-scale systems analysis, headed by Edwin W. Paxson, focused on optimization of Air Force strategic bombing of the Soviet Union and was finished in the pressure-packed days following the discovery that the Soviet Union had detonated its first atomic bomb years earlier than anyone in the U.S. military had predicted. As David R. Jardini has documented, this study, "Strategic bombing systems analysis," although advanced in design (it included calculations for more that 400,000 different configurations of bombers and bombs), was a debacle. Its assumptions were highly flawed; for example, it optimized on the basis of a single-strike campaign and obtaining the most damage for the least dollar cost.[17] As

16. The history of RAND's development of some of these methods is discussed in Jardini (ref. 11), chapt. 2.

17. Ibid., 60–63.

Fred Kaplan writes in his book, *The wizards of Armageddon*, "Air Force officers, almost all of whom were pilots, hated the study."[18] These pilots wanted to see the RAND systems analysis prescribe a bomber that would dramatically push the performance envelope of existing aircraft. What they got from RAND's systems analysis was a huge number of inexpensive, mass-produced, World War II-type bombers that used very conventional technology to deliver atomic bombs to Russian targets. The RAND analysis also ignored totally the by-no-means inconsequential matter that the U.S.'s stockpile of fissile material was breathtakingly low.

Following the disaster led by Paxson, RAND's researchers undertook a major review of systems analysis. Vast amounts of thought and ink were given over to solving the specification problem. The organization tried to address the problem in its next large-scale systems analysis, the Air Defense Study, but this project also ended in failure to develop a tenable, comprehensive approach to conducting air warfare via systems optimization methods. An internal RAND document characterized the organization's shift in thinking about systems analysis: "Upon completion of the Air Defense Study in 1951, it was thought that continued work in this field (by RAND) should be concentrated on selecting key component problems in which large payoffs may exist, and that no further broad systems analysis in this field should be contemplated."[19]

RAND thus abandoned its pursuit of a general theory of air warfare and devoted subsequent systems analysis to more restricted problems, such as how the United States should base its strategic forces and the value of missiles versus bombers in delivering offensive nuclear weapons. These more restricted studies met with enormous success and made RAND synonymous with systems analysis.[20] In turn, systems analysis became a widely diffused analytical methodology in the 1960s not only in defense-related work, but

18. Fred Kaplan, *The wizards of Armageddon* (New York, 1983), 89, as quoted in Jardini (ref. 11), 63.

19. Letter, L.J. Henderson to H. Rowen Gaither, 25 Jan 1950, as quoted in Jardini (ref. 11), 69.

20. Perhaps the most famous systems study carried out by RAND—at least the one that had the biggest impact on Air Force policy in the period up to 1962—was the bomber basing study led by Albert H. Wohlstetter. Space considerations prevent the discussion of this study here. It has been, however, well treated in the literature. Indeed, the attention accorded this basing study has served to distort the history of RAND as a research organization, for the basing study, its methods, and the style of its principal researchers have been equated with the overall "RAND style." For discussions of the basing study, see Bruce L.R. Smith, *The RAND Corporation: A case study of a nonprofit advisory corporation* (Cambridge, MA, 1966); Kaplan (ref. 18); Gregg Herken, *Counsels of war* (New York, 1985); and Marc Trachtenberg, "Strategic thought in America, 1952–1966," in idem., *Writings on strategy, 1961–1964, and retrospectives* (New York, 1988), 443–484.

also in civilian social policy research. RAND researchers stood at the forefront of this diffusion process.[21]

2. PIONEERING RAND RESEARCH AND RESEARCHERS

Hard science and engineering

Space research. Not long after it was founded as an independent institution, RAND contained seven research departments.[22] The largest of these units, at least in the early years, was the Missiles Department, which had been organized when RAND was a division of Douglas Aircraft. Headed by James E. Lipp, it issued RAND's first formal research study, *Preliminary design of an experimental world-circling space ship.*[23] Although it was produced in less than a month, the 324-page report remains one of the corporation's most widely cited projects. The Army Air Force commissioned the hastily prepared report because it needed to avoid being outflanked by the Navy Bureau of Aeronautics, which since 1945 had been working to build on the ideas of Werner von Braun and other captured German rocket team members. RAND delivered to its client a wide-ranging engineering study of the feasibility of designing, making, launching, and operating an artificial earth satellite. Its authors concluded that such an undertaking could be carried out with existing technology. The Air Force encouraged RAND to do additional work, which the organization delivered in a dozen reports in February 1947. RAND's final reports recommended a three-stage launch vehicle that could carry into orbit satellites for

21. A full account of the diffusion of RAND methods into the Pentagon in the early 1960s and then into social welfare research, analysis, and program control appears in Jardini (ref. 11). For the work of a for-profit systems engineering and analysis firm engaged in social welfare research, see Davis Dyer, "The limits of technology transfer: Civil systems at TRW, 1965–1975," paper delivered at conference on "The spread of the systems approach," Dibner Institute, Cambridge, Massachusetts, 3–5 May 1996, forthcoming in Thomas P. Hughes and Agatha Hughes, eds., *Systems, experts, and computers* [tentative title] (Chicago, under review). See also the paper delivered at the same conference by Jardini, "The transfer of systems thinking from the Pentagon to the Great Society."

22. In the first half of 1949, these departments and the percentages of the research budget they represented were as follows: Missiles (29%); Electronics (20%): Aircraft (13%); Mathematics (12%); Social Science (11%); Nuclear Physics (9%); and Economics (6%). These departments roughly correspond to those of the earlier period when RAND was an independent division of Douglas Aircraft. Names of the departments and their share of the research budget, of course, changed over the 1950s and early 1960s. Most significant among these changes was the merger in 1955 of the first three enumerated departments into a new Engineering Department, headed by Ed Barlow.

23. SM-11827, 2 May 1946.

communications relay purposes and for military reconnaissance.[24] These RAND studies allowed the Air Force to maintain a strong position in the Cold War pursuit of satellite technologies for communications and reconnaissance. Reconnaissance needs continued to grow as the Cold War grew more intense, and RAND produced additional studies on satellite reconnaissance. Its efforts reached a crescendo in 1953 and 1954 in a program known as Project FEED BACK upon which the Air Force based its Samos program. Samos lost out on technical grounds to the highly successful program run by the Central Intelligence Agency, Corona.[25]

The Air Force triumphed with another space technology, however—the intercontinental ballistic missile (ICBM)—thanks in part to the early missile research done at RAND. RAND's Missiles Department helped to position the Air Force's R&D organization to take command of the ICBM development program in 1954. The strategic imperatives to undertake actual development of the ICBM derived from the research findings of another RAND department, Nuclear Physics. RAND's role in the research and development of ballistic missile technologies decreased during the 1950s, however, as the Air Force developed more internal R&D capabilities and chose Simon Ramo and Dean Wooldridge's new firm (Ramo-Wooldridge Corporation) to manage the actual development of the ICBM and after the United States created the National Aeronautics and Space Administration (NASA) to manage the nation's panicked response to the Soviet Union's launch of the Sputnik satellites in the fall of 1957. Several RAND researchers, left RAND for NASA, and others went to the new Advanced Research Projects Agency (ARPA).

Aircraft. RAND's Aircraft Department flowed naturally out of the organization's roots in the Douglas Aircraft Company. This department carried out paper studies of aircraft and focused heavily on the technical problems of developing bombers and bomber support systems capable of delivering atomic weapons to the Soviet Union. These studies figured heavily in RAND's larger systems analyses of maximizing the Air Force's bang for a given number of bucks. Eventually, however, other departments at RAND superseded the Aircraft Department in overall research leadership.

24. These reports are RA-15021 through RA-15032, all issued 1 Feb 1947.

25. On RAND's work in communication and reconnaissance satellites, see Merton E. Davies and William R. Harris, *RAND's role in the evolution of balloon and satellite observations systems and related U.S. space technology* (Santa Monica, CA, 1988). On Corona, see Albert D. Wheelon, "Corona: The first reconnaissance satellites," *Physics today, 50:2* (Feb 1997), 24–30. Although the Air Force lost out to the CIA in the development of the first generation of reconaissance satellites, RAND continued to do work on the technology and contributed to subsequent generations of satellites used for military mapping, nuclear arms treaty verification, and early warning systems.

Nuclear physics. In its early days, RAND's Nuclear Physics Department focused on the development of atomic-powered bombers that possessed long range and flew at near-supersonic speeds. However, the creation of the Atomic Energy Commission (AEC), with its atomic monopoly in the United States, restricted RAND's access to important research data on atomic science and technology. Nevertheless, RAND's Nuclear Physics Department retained many distinguished atomic consultants, for example Luis Alvarez, Edwin McMillan, and Edward Teller. The department persevered in the paper-design of a nuclear-powered, radar-evading vehicle, the "Percojet," assertedly capable of delivering an atomic weapon anywhere in the Soviet Union. One problem with the aircraft, however, was its radiation hazard not only to those in the flight path of the plane but also to those who flew it.[26] Despite increasingly evident problems with the Percojet (refined studies showed that the plane's pilots were likely to be radiated to death before the plane reached its target), the world events of 1950 brought RAND's Nuclear Physics Department into what some have termed the "nuclear mafia" and others "the bomb shops" of the United States. The Korean War and the Truman Administration's decision to pursue the development of the hydrogen bomb led the AEC to develop stronger research ties with RAND's Nuclear Physics Department. The AEC became the dominant funder of the department, and the increased security restrictions of nuclear science and technology led to the department's eventual isolation from the rest of the organization.

RAND's access to the nation's atomic secrets led directly to the influential report written in early 1954 by Bruno Augenstein, "A revised development program for a ballistic missile of intercontinental range."[27] Originally classified as Top Secret (declassified with deletions in April 1974), this report played an important role in proceedings of the "Teapot" Committee, which recommended that the United States proceed at once to the development of an intercontinental ballistic missile. A member of the Electronics Department, Augenstein wrote this report before the United States had tested its hydrogen bomb, but he was privy to data suggesting that it would be more powerful—and more compact—than had originally been anticipated. With this information, Augenstein concluded that the H-bomb now made missiles an attractive alternative to bombers. The inaccuracy of missile guidance systems had previously made them relatively poor

26. For an enlightening eyewitness account of the U.S.'s attempts to build a nuclear-powered airplane, see Herbert York, *Race to oblivion* (New York, 1970), chapt. 4. See also, Richard G. Hewlett and Francis Duncan, *Atomic shield, 1947–1952* (University Park, PA, 1969), 71–74 and W. Henry Lambright, *Shooting down the nuclear plane* (Indianapolis, 1967).

27. SM-21, 8 Feb 1954.

offensive weapons, even if they carried atomic bombs. But tipped with bombs with yields in the megaton range, Augenstein argued, ICBMs would be awesome weapons, even if they were not perfectly accurate.[28]

The Nuclear Physics Department's early research for the AEC also played a role in shaping the work of one of RAND's most famous and controversial researchers, Herman Kahn, who in 1960 published the book *On thermonuclear war*.[29] Originally a member of the Physics Department, Kahn gained access to much of the research being done on what can conveniently be called "bomb effects"—what A-bombs and (later) H-bombs did when they exploded, how they affected various structures, environments, and organisms. These data became part of the calculus of the United States' war-making plans. Under Kahn, who brought to RAND expertise in Monte Carlo methods and also contributed to RAND's work in game theory and war simulation, the study of bomb effects became the basis for his belief that nuclear war was not only survivable but also in some sense winnable. Hence Kahn's strong recommendation that the nation undertake R&D on civil defense and invest heavily in the protection of civilian populations.[30] Kahn also advocated research on the regeneration of the

28. The history of the Teapot Committee and the Air Force's ballistic missile program is reviewed in Jacob Neufeld, *The development of ballistic missiles in the United States Air Force, 1945–1960* (Washington, D.C., 1990) and Edmund Beard, *Developing the ICBM: A study in bureaucratic politics* (New York, 1976). See also John Clayton Lonnquest, "The face of Atlas: General Bernard Schriever and the development of the Atlas intercontinental ballistic missile, 1953–1960" (Ph.D. diss., Duke University, 1996) and Donald MacKenzie, *Inventing accuracy: A historical sociology of nuclear missile guidance* (Cambridge, MA, 1993). York (ref. 26), presents an eyewitness account of the committee's operations.

29. Herman Kahn, *On thermonuclear war* (Princeton, NJ, 1960). Parts of this book were issued earlier as RAND Research Memoranda (RM's) and Papers (P's), but the book itself was not an official RAND research product.

30. Kahn's advocacy for civil defense initiatives in the United States was supported in part by the research of his RAND colleague Leone Gouré on civil defense in the Soviet Union, part of the Social Science Department's efforts in Soviet studies, which will be discussed later in this paper. Gouré produced several RAND research memoranda and papers, and from them he published *Civil defense in the Soviet Union* (Berkeley, 1962). Kahn had begun to work on civil defense-related issues as early as 1957 when RAND initiated, under Kahn's direction, what was termed a "Non-military defense study." Issued 4 Apr 1958, the report of this study, "Non-military defense study—1957," remains classified. It contains papers written by numerous RAND researchers, who explore a wide range of issues related to civil defense, including a study of Soviet civil defense efforts written by R. Moorsteen. D(I)-5085-RC, RAND Corporation, Santa Monica, California. RAND also sponsored in May 1957 a conference on civil defense and military target hardening called the "Protective construction conference." The papers at this conference were gathered Symposium on Protective Construction, *Proceedings*, S-69, 27–29 May 1957, RAND Corporation. The volume remains classified. Kahn later issued his own paper from that conference as a RAND Document, "Why shelters?" D-5392, 24 Jul 1958, RAND Corporation. In the preface to this document, Kahn implies that one of RAND's research managers, Larry Henderson, was not happy with the paper's distribution out-

economy and society following a nuclear holocaust, the most effective means of population regeneration, and ways to minimize and overcome genetic damage caused by high radiation exposure. Most people found these studies highly unpalatable.[31]

Electronics. RAND's Electronics Department never distinguished itself in terms of its research, research methods, or research findings to the same extent as some of RAND's other departments. Indeed, although nominally the second biggest department at RAND in 1949, the Electronics Department spent most of its money contracting for research from established electronics firms, including Radio Corporation of America, Collins Radio, and AT&T Bell Telephone Laboratories. The department's role at RAND centered on providing critical information to RAND's systems analyses, many of which turned on matters such as capabilities of radar, effectiveness of electronic countermeasures, electronic communications technologies, and the like. The department also encouraged research on early "stealth" technologies such as radar-absorbent paints and other materials and participated in work on upper atmospheric physics.

From military worth to mathematics, economics, and social sciences

When RAND was constituted as a division of Douglas Aircraft, it included an organization known as the Evaluation of Military Worth Section. Consistent with RAND's original goal of developing a complete "science of warfare," the assignment of this section was to create a general theory of "military worth." To a large extent, this undertaking built upon the work of an organization created during World War II, the Applied Mathematics Panel (AMP), which operated under the Office of Scientific Research and Development.[32] AMP's director, the applied mathematician

side the Air Force and that another RAND researcher, George Clement, thought the paper was, on the whole, "undesirable." The paper strongly advocated hardening of U.S. Air Force assets, such as missile silos and bomber hangers.

31. On Kahn and his work on thermonuclear war, see Sharon Helsel, "The comic reason of Herman Kahn: Conceiving the limits to strategic uncertainty in 1960" (Ph.D. diss., University of California, Santa Cruz, 1993). On Kahn and early work on Monte Carlo methods and applications, see Peter Galison, "Computer simulations and the trading zone," in Peter Galison and David J. Stump, eds., *The disunity of science: Boundaries, contexts, and power* (Stanford, CA, 1996), 142–143. Kahn wrote an extensive analysis of the Monte Carlo method, "Application of Monte Carlo," RM-1237-AEC, 19 Apr 1954, revised 27 Apr 1956, RAND Corporation.

32. On the history of the AMP and Weaver's involvement with it, see Larry Owens, "Mathematicians at war: Warren Weaver and the Applied Mathematics Panel, 1942–1945," in David E. Rowe and John McCleary, eds., *The history of modern mathematics, Volume II: Institutions and applications* (Boston, 1989), 287–305. See also the participant account of W. Allen Wallis, "The statistical research group, 1942–1945," *Journal of the American Statistical Association, 75* (1980), 320–330.

and program director at the Rockefeller Foundation, Warren Weaver, was an early and important consultant to RAND. During the war Weaver had worked with Collbohm on operations research problems for the Air Force. Under Weaver, AMP had developed the concept of military worth as the key to a general science of warfare during the closing months of World War II, but it had been unable to develop the concept into a robust set of analytical tools. Three former members of Weaver's AMP staff joined RAND's Evaluation of Military Worth Section—applied mathematicians John D. Williams, Olaf Helmer, and Edwin Paxson—and insured that the ultimate goal of Weaver's AMP remained in place at RAND.

Consistently described by his former colleagues as brilliant and broad-minded, Williams is reputed to have played a critical role in shaping the Military Worth Group, and the future of RAND, by insisting on the inclusion of social scientists, as had the AMP. No direct evidence of this claim has been found, however; the record suggests that from the outset the Military Worth Section included social scientists. The critical issue turned not on who was in the research group but what factors were being considered in the research. Williams and Helmer met with several consultants in December 1946 to hash out a research program for the section.

Among the consultants were Weaver and two other veterans from the AMP's Statistical Research Group, Princeton mathematician Samuel Wilks and his protégé and Harvard-bound statistician, Frederick Mosteller.[33] Discussion centered on how to quantify the concept of "military worth" and how to use the concept for the purposes of planning and executing a war. Wilks believed strongly in pursuing a conservative approach, which he termed "weapon-target coverage analysis." This approach demanded knowledge of weapons and their physical effects, numbers of weapons available, effectiveness of countermeasures, and the like. The further that analyses moved away from these hard data, Wilks maintained, the more uncertainty entered the picture and the greater the problem of obtaining reliable results. At the other end of the spectrum, RAND's Olaf Helmer advocated taking a behavioralist and contextualist approach and developing analytical methods for decision-making under conditions of uncertainty. Ultimately the group settled on something closer to Helmer's than to Wilks's approach, a decision that led to some of RAND's most outstanding research products and the emergence of some of its most distinguished researchers. These successes did not come without discord, however, and differences within the Military Worth Group soon fissioned it into three

33. On Wilks, see his biographical entry in *Dictionary of scientific biography*, s.v., Wilks, Samuel. On Mosteller, see his biographical entry in *Contemporary authors*, v. 19–20, s.v. Mosteller, Frederick.

separate departments, Mathematics, Economics, and Social Sciences.[34] Between 1946 and the early 1960s, RAND researchers in all three departments pioneered a variety of tools and approaches to decision-making under conditions of uncertainty.

Applied mathematics. Out of the work of the Military Worth Section and in response to the limited (static) conditions in which current operations research methods could be effectively applied, George Dantzig, working as a consultant to RAND and mathematical advisor to the Air Force, made major advances in linear programming. His big step was the development of what he called the "simplex method" for the solution of previously unapproachable problems in optimization. Dantzig laid out his simplex method in a paper that remained classified until 1951, shortly before he joined RAND as a full-time researcher. While at RAND he wrote more than seventy Research Memoranda and Papers, almost fifty of which appeared in the open literature in operations research and applied mathematics.[35]

Richard Bellman also carried out major work in applied mathematics under RAND's aegis and was probably its most distinguished mathematician. Like many RAND researchers, he entered the organization after he had spent a couple of summers working as a consultant at RAND, where he was, as he noted in his autobiography, "exposed to a number of significant mathematical ideas [such as]...[l]arge systems, effective numerical solutions, the application of mathematics to the social sciences, mathematical model making, the theory of games, and branching processes."[36] He found these ideas and the problems associated with them sufficiently exciting to leave a tenured faculty position at Stanford to join RAND fulltime in September 1952. During his thirteen-year tenure at RAND, Bellman

34. Given that RAND viewed itself as a research university without students, RAND's organization evolved to follow clear parallels to disciplinary departments in leading research universities. Hence at RAND, researchers were affiliated with departments that had clear professional disciplinary identities, which facilitated the movement of researchers back and forth from RAND to leading universities. RAND researchers looked to their disciplines in which to publish their work and thereby maintained high standards of research and knowledge production. To complement this departmental/disciplinary organization, however, RAND organized much of its project research along interdisciplinary lines by bringing together researchers from various departments, which fostered all the creativity and tensions that distinguishes such research in a university. Thus, almost from the beginning, RAND possessed what would later be termed a "matrix organization."

35. On Dantzig, see *Who's who in America, 1980–1981*, s.v. Dantzig, George B. On the history of the simplex method, see George B. Dantzig, "Reminiscences about the origins of linear programming," *Operations research letters, 1:2* (1981), 43–48, and Dantzig, *Origins of the simplex method*, Technical Report SOL 87–5 (Systems Optimization Laboratory, 1987).

36. Richard Bellman, *Eye of the hurricane: An autobiography* (Singapore, 1984), 142.

encountered but eventually overcame severe problems with retaining his security clearance. While he was confronting these problems, some RAND researchers shunned him. In recounting these days in his autobiography, Bellman does not make clear, however, whether he was shunned because he was suspected of being a communist or because it had become widely known that he had given the FBI the names of several communists he had known at Princeton in the late 1940s.[37] These problems notwithstanding, Bellman made enormous contributions to RAND's program in applied mathematics. His principal contribution is best captured by the broad class of methods he called "dynamic programming," which opened up further avenues in optimization (min/max, shortest path, etc.) under changing conditions (hence under conditions of uncertainty). In the period through 1962, Bellman produced some seventy-five non-classified Research Memoranda and approximately 250 Papers, the bulk of which appeared in print in the open literature.[38] In addition, he made early contributions to RAND's work in game theory.

Game theory. From the organization's outset, John von Neumann was a critical advisor to RAND and mentored several key RAND researchers. His work inspired a deep and diverse amount of research at many institutions. RAND was no exception. To researchers in the Military Worth Section, von Neumann and Oskar Morgenstern's *Theory of games and economic behavior*, published in 1944, appeared to offer an ideal approach to solving problems of warfare and decision-making.[39] Consequently, RAND became unquestionably the leading center for the development of game theory between 1946 and 1962. In addition to Bellman, such giants as Lloyd Shapley, Melvin Dresher, J.C.C. McKinsey, Merrill Flood, L.J. Savage, John Nash, and Kenneth Arrow carried out research in game theory at RAND or under RAND's aegis.[40] In 1954, John D. Williams, head of the

37. On Bellman's security clearance problems, see Bellman (ibid.), "Guilt by association," chapt. 15, 238–248.

38. Bellman's book, *Dynamic programming* (Princeton, 1957), brought together much of his early work carried out at RAND. For a complete listing of Bellman's output of unclassified scholarship, see *Index of selected publications of the RAND Corporation, 1946–1962* (Santa Monica, CA, 1962) and *Selected RAND abstracts, 1963–1972* (Santa Monica, CA, 1973). On Bellman's reflections on his career at RAND, Bellman (ref. 36), 173–226.

39. On the early history of game theory, see Robert J. Leonard, "From parlor games to social science: Von Neumann, Morgenstern, and the creation of game theory 1928–1944," *Journal of economic literature, 32* (1995), 730–761.

40. A quick idea of RAND's output of game theoretic scholarship can be gained by looking at the publications of the above-mentioned men in *Index of selected publications of the RAND Corporation, 1946–1962*. This volume consists only of non-classified work. Greater output is recorded in the classified *Project RAND publications index* (2 vols., Santa Monica, CA, 1963), which indexes classified reports. Moreover, a simple perusal of R. Duncan Luce and Howard Raiffa's bibliography in their *Games and decisions: Introduction and critical survey* (New York, 1957) reveals the extent of their reliance upon RAND's work in game theory.

Mathematics Department, published a synthetic book on game theory, *The compleat strategyst, being a primer on the theory of games of strategy*, which as the old-fashioned title indicates, sought to enlighten the educated reader about game theory.[41]

In the context of the Cold War, RAND's early work on game theory promised powerful results.[42] The emergence of the Soviet Union as "the enemy" and notions of a possible single, intense exchange of nuclear weapons between the Soviet Union and the United States offered a nearly perfect parallel to the simple building block of game theory—zero-sum, non-iterative, two-person games—which in turn provided the game theorists with a way to mathematize strategies and outcomes. But as real-world conditions and contingencies entered the analysis, formalizing such conditions in game theory proved to be too difficult. Non-zero-sum games consisting of multiple moves in which a changing number of players could learn, mix strategies, and pursue non-rational behavior eluded RAND researchers' formalization abilities. As Charles Hitch, head of RAND's Economics Department, noted, "For our purposes, Game Theory has been quite disappointing."[43] In spite of these disappointments and the eventual departure of Shapley, McKinsey, and Dresher, among others, RAND continued to have a presence in game theory. This work, however, was overpowered by the output of the Economics Department, which came to be one of the most vital research units within the corporation.

Economics. Almost from its creation in 1946, RAND established important ties with the Cowles Commission for Research in Economics at the University of Chicago, a pivotal institution in the rise of modern economics. Led by luminaries like Tjalling C. Koopmans and Jacob Marschak, the Cowles Commission played a major role in the mathematization of economics and the development of econometrics.[44] Many of RAND's economists had worked with the Cowles Commission and vice versa. As Nobel

41. (New York, 1954).

42. Philip Mirowski's "When games grow deadly serious: The military influence on the evolution of game theory," in Craufurd D. Goodwin, ed., *Economics and national security: A history of their interaction*, annual supplement to volume 23, *History of political economy* (Durham, 1991) is quite helpful in this vein, as is Robert J. Leonard, "Creating a context for game theory," in E. Roy Weintraub, ed., *Toward a history of game theory*, annual supplement to volume 24, *History of political economy* (Durham, 1992).

43. Quoted in William Poundstone, *Prisoners' dilemma* (New York, 1992), 168. Poundstone's book provides a reasonably accurate portrayal of game theory at RAND and RAND's role in game theory.

44. On the Cowles Commission, see Carl F. Christ, "The Cowles Commission's contributions to econometrics at Chicago, 1939–1955," *Journal of economic literature, 32* (1994), 30–59.

laureate Herbert A. Simon has recently written, "For centrality to the postwar quantitative social sciences, the Cowles Commission and the RAND Corporation were definitely the places to see and to be seen."[45] The association between RAND and the Cowles Commission became formalized in 1949 when RAND engaged the Cowles Commission to undertake research on the theory of resource allocation.[46] Rather than being a simple work-for-hire contract, the agreement served to bring Cowles-supported economists into the problem domain of RAND.

The work of Nobel laureate Kenneth J. Arrow provides a good example of the relationship between the two institutions. Long after finishing his formal course work in economics at Columbia but still searching for a good dissertation topic, Arrow joined the Cowles Commission in 1947 as a research associate. He then spent the summer of 1948 at RAND contemplating the problems of applying game theory to Soviet-U.S. relations. Arrow describes how his work quickly evolved:[47]

> When we were at RAND together, [Olaf] Helmer remarked that there was something that bothered him about game theory or about its applications. We wanted to talk about the US, the USSR, and Western Europe as players, but they are not like people, [so] in what sense do they have utility functions? How can we apply game theory where it is essential to have utility functions? Since when does the US have a utility function? "Oh," I said, "that is nothing. Abram Bergson has written on this type of thing." "Oh," he said, "would you write an exposition of this?" Well, that was the thing that led to the social choice book.

In July 1949, Arrow, once again in Santa Monica for the summer, completed RAND RM-291, "Social choice and individual values." This report not only fulfilled the requirement for his Columbia University dissertation in economics (the degree was awarded in 1951), but it also appeared in 1951 as a book by the same title in the Cowles Commission's monograph series with John Wiley & Sons.[48] Arrow's Nobel Prize citation singles out this book as being central to the development of modern economics.

45. Herbert A. Simon, *Models of my life* (New York, 1991), 116.

46. *Economic theory and measurement: A twenty year research report, 1932–1952* (Chicago, 1952), 46–47.

47. George R. Feiwel, "Oral history I: An interview [with] Kenneth J. Arrow," in Feiwel, *Arrow and the ascent of modern economic theory* (New York, 1987), 193. Helmer, incidentally, was educated as a philosopher.

48. C. Daniel Vencill, "Kenneth J. Arrow, 1972" in Bernard S. Katz, ed., *Nobel laureates in economic sciences: A biographical dictionary* (New York, 1989), 9–30, on 12; Kenneth J. Arrow, *Social choice and individual values* (New York, 1951) [Cowles Commission Monograph No. 12].

Under the direction of the British-trained economist Charles J. Hitch, RAND's Economics Department built a powerful reputation for its work not only in game-theoretic economics and resource allocation theory but also in two other areas, program budgeting and management methods and economics of R&D. The economists who formed the Economics Department out of the breakup of the Military Worth Section rode their way to the top of RAND's reputation hierarchy by applying tried and true economic principles to military problems. They laid claim to a science that addressed the question of how best to allocate scarce resources, for example, in conducting a war or maintaining a peace.[49] Two additional factors contributed to the rise of the Economics Department. First, the Korean War and the U.S.'s forging of the North Atlantic Treaty Organization shook RAND out of its preoccupation with a nuclear exchange with the Soviet Union as the central problem facing both RAND and the United States. RAND thus took up issues of tactical air warfare and logistics systems, problems with which economists could deal using the applied mathematical methods of Dantzig, Bellman, and others. Second, the negative response to RAND's first two major systems analyses allowed Hitch and his colleagues to pull back into more discrete and manageable problems—what Hitch termed "suboptimization" problems. Such an approach, Hitch maintained, allowed RAND to get around the "specification problem" that had thwarted its wider, intractable systems analyses.

Hitch and his colleagues developed methods to guide choices among alternative weapons systems and among a variety of factors in other sorts of systems. These methods brought together several of the approaches being pursued at RAND—cost benefit analysis, optimization methods including linear and dynamic programming, and systems analysis. Out of this work emerged the basic text in the field, Charles J. Hitch and Roland N. McKean's *The economics of defense in the nuclear age*, which soon became the operation manual for the "McNamara revolution" in the Kennedy administration's Pentagon.[50]

RAND's Economics Department also pioneered in the development of the economics of R&D (or the economics of technical change). Work in this area grew out of increasing dissatisfaction with one of the fundamental

49. Two additional departments emerged from the Economics Department during the early 1950s, both of which served to extend RAND's reputation in economics as applied to defense. David Novick, a major figure in cost analysis, established the Cost Analysis Department in early 1950, and Stephen Enke, an economist, founded the Logistics Department in 1953.

50. Charles J. Hitch and Roland N. NcKean, *The economics of defense in the nuclear age* (Cambridge, 1960). Hitch became Robert McNamara's Comptroller soon after McNamara took office in 1961. In addition, McNamara hired several other RAND researchers, all of whom were schooled in Hitch and McKean's text.

premises of systems analysis—that all contingencies could be accommodated in a good systems analysis and that the method could therefore guide decision-makers in choosing such things as future weapons systems "optimally." A second, related concern also motivated the work: concurrent engineering. During the 1950s, segments of the Air Force argued that the acquisition of future weapons systems could be so completely specified that even during the design stage, production equipment, tooling, and the like could be acquired and designed so as to save time in the deployment of the final product. A few economists at RAND grew increasingly skeptical about the ability of systems analysis to factor in such contingencies as scientific and technological change, and for the same reasons they objected to the premises of concurrent engineering. Consequently, encouraged by Frank Collbohm, they launched a relatively small project to carry out case studies of the weapons development process in particular and selected other new technologies in general. Headed by the Harvard-educated economist, Burton Klein, this group produced a number of case studies, all of which supported the group's emerging view that R&D programs could not be efficiently managed in a strictly hierarchical, centralized organization in which procurement was pursued in parallel with R&D. The group prepared two different once-classified versions of Air Force briefings; the essence of both are fully embodied in an article by Klein, published in *Fortune* magazine in 1958. He addressed the widely perceived threats to the security of the United States signalled by the Soviet Union's Sputnik launches:[51]

> Better planning, stricter control from the top, elimination of the "wasteful duplication" of interservice competition—this sums up the general belief on what we must do about military research and development if we are not to be fatally out-distanced by the Russians.
>
> The truth is precisely the reverse. The fact is that military research and development in this country is now suffering from too much direction and control. There are too many decision makers, and too many obstacles are placed in the way of getting new ideas into development. R. and D. is being crippled by the official refusal to recognize that technological progress is highly unpredictable, by the delusion that we can advance rapidly and economically by planning the future in detail.

Although it maintained a tight focus on military R&D policy, RAND's economics-of-R&D project also yielded two of the foundational papers in the field: Richard Nelson's "The simple economics of basic scientific

51. Burton Klein, "A radical proposal for R. and D.," *Fortune*, *57* (May 1958), 112–113, 218, 222, 224, 228. Quotation appears on 112.

research," and Kenneth J. Arrow's "Economic welfare and the allocation of resources for invention."[52] The findings in these two classic papers, however, derived more from the larger Cold War context, particularly the Sputnik crisis, in which they were written than from the empirical work being done by the group. Both Nelson's and Arrow's papers formalized the opportunistic view promulgated by the American scientific community that the reason the United States had failed to beat the Soviet Union into space was because the U.S. was not investing enough in basic scientific research.[53] Nelson's and Arrow's papers provided appealing economic theories as to why the nation would systematically underinvest in basic research. Their theories had clear policy implications: the U.S. government should invest more in basic research owing to "market failures" in the private sector. These theories have been largely internalized within the now dominant neoclassical economic tradition in spite of recent criticism from several non-orthodox economists.[54]

Artificial intelligence. RAND was also one of the important research sites for the development of what became known as "artificial intelligence."[55] For once RAND was not the lone pioneer of the field. Those

52. Richard R. Nelson, "The simple economics of basic scientific research," *Journal of political economy, 67* (1959), 297–306, and Kenneth J. Arrow, "Economic welfare and the allocation of resources for invention," in Richard R. Nelson, ed., *The rate and direction of inventive activity: Economic and social factors* (Princeton, 1962).

53. David A. Hounshell, "The medium is the message, or how context matters: The RAND Corporation builds an economics of innovation, 1946–1962," forthcoming in Hughes and Hughes, eds. (ref. 21).

54. For recent views on the place of Nelson's and Arrow's work see Wesley Cohen, "Empirical studies of innovative activity," in Paul Stoneman, ed., *Handbook of the economics of innovation and technological change* (Oxford, 1995), 182–264. See also Alfonso Gambardella, *Science and innovation: The US pharmaceutical industry during the 1980s* (New York, 1995), 1–16; Partha Dasgupta and Paul A. David, "Information disclosure and the economics of science and technology," in George R. Feiwel (ref. 47), 519–542; Partha Dasgupta and Paul A. David, "Toward a new economics of science," Center for Economic Policy Research, Stanford University, Publication No. 320; David C. Mowery, "Economic theory and government technology policy," *Policy sciences, 16* (1983), 27–43; David C. Mowery and Nathan Rosenberg, *Technology and the pursuit of economic growth* (New York, 1989), 3–17; Nathan Rosenberg, "Why do firms do basic research (with their own money)?" *Research policy, 19* (1990), 165–174; and Paula E. Stephan, "The economics of science," *Journal of economic literature, 34* (1996), 1199–1235.

55. The history of artificial intelligence is treated in the following works: Allen Newell and Herbert A. Simon, "Historical addendum" in Simon, *Human problem solving* (Englewood Cliffs, N.J., 1972); Pamela McCorduck, *Machines who think* (San Francisco, 1979); James Fleck, "Development and establishment in artificial intelligence," in Norbert Elias et al., *Scientific establishments and hierarchies*, Vol. 6, *Sociology of the sciences: A yearbook* (Boston, 1982); Simon (ref. 45); and Daniel Crevier, *AI: The tumultuous history of the search for artificial intelligence* (New York, 1991).

who attended the "Dartmouth Summer Research Project on Artificial Intelligence" in 1956 constitute a reasonably good proxy for the American pioneers of the field.[56] Funded by the Rockefeller Foundation, the two-month project brought together in Hanover, New Hampshire, men who were ready "to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it."[57] Although the conference failed to yield the epiphany hoped for by its organizers, it nevertheless served to solidify the field, fix its name as "artificial intelligence," and create a strong sense of rivalry (sometimes healthy, sometimes not) among those pioneers.[58] It also helped to turn on or enlarge a research revenue stream that would help to make four institutions into the principal locus of the first wave of AI work: MIT, Stanford (after John McCarthy left Dartmouth for Palo Alto), Stanford Research Institute (SRI), and RAND/Carnegie Tech (now Carnegie Mellon University).[59]

Herbert Simon, later a winner of a Nobel Prize in economics, his protégé Allen Newell, and J.C. Shaw, a computer scientist/programmer, constituted the joint undertaking of RAND and Carnegie Tech in artificial intelligence.[60] One of the founding faculty members of Carnegie Tech's

56. John McCarthy (Dartmouth), Marvin Minsky (MIT), Nathaniel Rochester (IBM), and Claude Shannon (Bell Laboratories) organized the project. Those attending also included Trenchard More, Arthur Samuel (IBM), Oliver Selfridge (MIT), Ray Solomonoff (MIT), Herbert Gelernter (IBM), and Allen Newell and Herbert Simon (RAND and Carnegie Tech).

57. "Project proposal to the Rockefeller Foundation," as quoted in McCorduck (ref. 54).

58. As Newell and Simon point out in *Human problem solving*, Marvin Minsky also managed to write the first draft of and solicited feedback on his influential, programmatic article, "Steps toward artificial intelligence," Institute of Radio Engineers, *Proceedings, 49* (1961), 8–29.

59. James Fleck maintains that because the military (i.e., the Air Force and the Department of Defense's Advanced Research Projects Administration) were the principal funding agents—75% of AI funding derived from these sources between 1954 and 1964—it could skirt typical peer review processes and thereby build this small number of centers of AI excellence. "Development and establishment" (ref. 54), 181.

60. Space considerations prevent an adequate discussion of RAND's early work on the digital computer, which was central to its work in artificial intelligence and many other domains of knowledge in which RAND pioneered. RAND was one of the first institutions in the United States to have an advanced digital computer. With the overall architecture designed by John von Neumann and construction and operation overseen by one of von Neumann's students, Willis Ware, who became RAND's foremost computer authority, RAND's computer was the first operational, core memory computer. It was named "Johnniac" in honor of its creator and important RAND consultant. On this development, see F.J. Gruenberger, "History of the Johnniac," *Annals of the history of computing, 1* (1979), 49–64. RAND also did pioneering work on programming languages and user architecture, including the famous JOSS (Johnniac Open-Shop System). See C.L. Baker, "JOSS Johnniac Open-Shop System," in R.L. Wexelblat, ed., *History of programming languages* (New York, 1981) and Shirley L. Marks, "JOSS: Conversational computing for the nonprogrammer," *Annals of the history of computing, 4* (1982), 35–42.

Graduate School of Industrial Administration (GSIA, an institution committed to management education based on the production of new, largely quantitative social-scientific knowledge like that being produced at RAND), Simon spent several of his summers during the 1950s working at RAND on research sponsored by the Air Force.[61] The core of Simon's work was (and still is) the cognitive dimensions of human decision-making. He and his collaborators (Newell, James March, and Richard Cyert) produced fundamental scholarship in this domain.[62] RAND played a vital role in fostering Simon and Newell's work in artificial intelligence.

Some of those who attended the Dartmouth summer seminar had already taken up the challenge (or would soon do so) presented by Claude Shannon in 1950 of developing a computer program to play world-class chess.[63] Others began writing computer programs to play checkers and other games. RAND thought this work important for developing and testing theories about human intelligence and decisionmaking and building computer programming capabilities. The AI pioneers devoted enormous amounts of time, energy, and money to game programs, and their efforts received both praise and criticism.[64]

General problems also commanded the attention of the AI pioneers. By the time of the Dartmouth seminar, Simon and Newell had already developed at RAND their Logical Theorist program, which could prove some elementary theorems found in Alfred N. Whitehead and Bertrand Russell's *Principia mathematica*. Between the Dartmouth summer seminar

61. On Simon's involvement with the founding of GSIA, see Robert E. Gleeson and Steven Schlossman, "The many faces of the new look: The University of Virginia, Carnegie Tech, and the reform of American management education in the postwar era," in Steven Schlossman et al., *The beginnings of graduate management education in the United States* (Santa Monica, 1994).

62. Simon's autobiography (ref. 45), is an excellent source for his view on his own work. Newell, who had dropped out of graduate school in mathematics at Princeton, finished his Ph.D. under Simon at Carnegie Tech. in 1957. Together Simon and Newell wrote several RAND RM's and P's and *Human problem solving* (ref. 55). Simon and Yale-educated James March (Ph.D., 1953) produced their classic work, *Organizations* (New York, 1958) while March was on the faculty of Carnegie Tech. March was affiliated with RAND as a consultant from 1965 to 1969. He collaborated with another of Simon's colleagues and eventual president of Carnegie Mellon University, Richard Cyert, to produce the highly influential book, *A behavioral theory of the firm* (Englewood Cliffs, N.J., 1963).

63. Claude Shannon, "Automatic chess player," *Scientific American, 182:2* (1950), 48–51 and Shannon, "Programming a computer for playing chess," *Philosophical magazine, 41* (1950), 256–275. A researcher at Bell Telephone Laboratories, Shannon is widely regarded as a principal founder of information theory.

64. See Hubert L. Dreyfus, *What computers can't do: A critique of artificial reason* (New York, 1972), for an account that conveys the nature of the (self) praise and the criticism.

of 1956 and the summer of 1958, when Simon and Newell ran a seminar at RAND on computer simulation and psychology sponsored by the Ford Foundation, the RAND group had developed a chess program, which, as Simon has recently admitted, "played poor chess," but which they considered a major stride in artificial intelligence at the time. Simon, Newell, and Shaw had also made progress on a larger set of problems and by 1960 had developed the General Problem Solver, which captured in computer language their ideas about "means-ends analysis" as a heuristic of human problem solving. As the title of their program indicates, they believed their work constituted a general, if not universal, problem-solving device that captured the complexity of the human mind, which they interpreted as an information processing system.[65]

From 1957 to 1961 Newell, who had first joined RAND in 1950, held joint positions with RAND and Carnegie Mellon. In 1961, he joined Carnegie Mellon fulltime. He and Simon continued to work together, and served as consultants to RAND. Newell's work there not only encompassed artificial intelligence, but also included man-machine systems and individual and group learning in machine-driven environments. With others, Newell worked on the design, construction, and operation of the Systems Research Laboratory created to examine how human-machine systems perform under stress.[66] The laboratory simulated an Air Defense Direction Center and became a major training ground for operators of the Air Force's SAGE air defense system. Indeed, the work on man-machine simulation first brought Simon (a new consultant to RAND in 1952) into contact with Newell during the development of the Systems Research Laboratory. Eventually, RAND's systems simulation laboratory grew so big and its operation became so routine that it was spun out of RAND as the Systems Development Corporation.[67]

Soviet studies. Although not conventionally considered a "science," Soviet studies were pursued at RAND with the same analytical rigor and toward the same ends as atomic bomb effects, advanced aircraft design, bomber base vulnerability, and the economics of R&D. The objective of RAND's diverse studies of the Soviet Union was to know the enemy and to

65. See Newell and Simon (ref. 55) for a discussion of Logical Theorist and General Problem Solver. See also Simon (ref. 45). For critiques of their claims about these programs; see Dreyfus (ibid.) and Joseph Weizenbaum, *Computer power and human reason* (San Francisco, 1976).

66. R.L. Chapman, W.C. Biel, J.L. Kennedy, and A. Newell, "The Systems Research Laboratory and its program," RM-890, 7 Jan 1952, RAND Corporation. See also Simon's discussion of SRL in (ref. 45).

67. On the history of SDC, see Claude Baum, *The systems builders: The story of SDC* (Santa Monica, CA, 1981).

incorporate that knowledge into the Air Force's overall strategy.[68] Also, according to a former RAND research director, RAND's work in this area, especially its research on the Soviet economy, served as a check on the intelligence estimates of the Central Intelligence Agency.[69] Two topics deserve particular mention: the Soviet economy and war-making capability, and Soviet decision-making.

RAND supported a large investigation of the Soviet economy led by some of its closest students, including Abram Bergson, Alexander Gerschenkron, and Norman M. Kaplan. Beginning in late 1948 and working in conjunction with the Air Force-funded Russian Research Center at Harvard University, RAND tried to establish accurate data on prices, wages, investment, gross domestic product, sectoral outputs, and growth rates of the Soviet Union. It proved to be a major enterprise that came to enroll many of Bergson's and Gerschenkron's graduate students. Among the results were such fundamental works on the Soviet economy as Bergson's *The real national income of Soviet Russia since 1928* (1961) and Gerschenkron's *Economic backwardness in historical perspective* (1962). Gerschenkron and his students also produced a series of dollar indexes to Soviet output in the coal, petroleum, electricity, iron and steel, and heavy machinery industries. These indexes, which helped to establish benchmarks from which estimates of overall Soviet economic growth could be made, were produced between 1951 and 1955.[70] Research on the Soviet economy also yielded information about Soviet war-making capacity.[71]

RAND's studies of Soviet decision-making and Soviet politics, which were produced mainly by researchers in the Social Sciences Department, spurred RAND's researchers in their efforts to win the Cold War and to ensure that the United States would emerge the victor from a hot war with the Soviet Union. Unquestionably, the most influential of the research products that RAND's Soviet political specialists turned out was Nathan C. Leites's *The operational code of the Politburo* (1951), billed on its dust jacket as a "systematic analysis of the political strategy of Communism and

68. The history of Soviet studies in the United States is not developed. But see Charles Thomas O'Connell, "Social structure and science: Soviet studies at Harvard," (Ph.D. diss., UCLA, 1990). O'Connell documents the importance of Air Force and other governmental funding for the nature and direction of Soviet studies at Harvard.

69. Telephone conversation with Gustave H. Shubert, Senior Fellow and Corporate Advisory, The RAND Corporation (2 Jul 1996).

70. See the following RAND Corporation reports: R-197, RM-804, RM-1042, RM-1055, RM-1282, and P-560.

71. J.A. Kershaw, one of RAND's principal researchers on the Soviet economy, and J. Hirshleifer were among those producing such studies. Kershaw played a major role in brokering the relationship between RAND and Harvard's Russian Research Center.

the rules by which it operates." Born in St. Petersburg in 1912, Leites emigrated to the United States in 1936 and became a fervent anti-Bolshevik. He maintained an affiliation with the University of Chicago before World War II, worked in Washington during the war, and joined RAND in 1947. He remained until 1962 when he took a professorship at Chicago. *The operational code of the Politburo* brought together the methods of "quantitative semantics" (Leites had written a book on it too)[72] with one of the central premises that drove so much of RAND's research, that humans, whether as individuals or as groups, make decisions based upon "rules" that can be teased out of the mind or the organization and formalized both qualitatively and quantitatively. By studying the founding documents of Bolshevism (those of Lenin and Stalin), Leites deduced a set of rules that he said governed the Soviet Union's relations with "the outside world." As Leites put the matter, "The intention is not to discuss the major theories of Leninism-Stalinism but to discover the rules which Bolsheviks believe to be necessary for effective political conduct....[A] study of the sacred texts of Bolshevism—the works of Lenin and Stalin—seems necessary if we want to increase our skill in predicting Politburo behavior."[73]

The operational code deduced by Leites spanned some ninety pages under twenty headings (or chapters). The first rule under "The calculus of the general line," reads:[74]

> 1. Every line of Bolshevik conduct is either prescribed or forbidden. It is prescribed if it will maximize the power of the Party. It is forbidden if it will not. There is little behavior that is merely tolerated, or recommended.

The first three rules under "Advance" are: [75]

> 1. The only way in which the Party can achieve gains is by intense "struggle."
> 2. The Party must take possession of every no man's land; otherwise the enemy will.
> 3. However "backward" a country may be, the Party must always strive to gain control over it.

To those who had read George F. Kennan's famous article in *Foreign affairs*, "The sources of Soviet conduct" (1947), Leites's rules must have

72. With Harold D. Lasswell, Leites published a book in 1949 that sought to put a scientific foundation under the study of semantics, *The language of politics: Studies in quantitative semantics* (New York, 1949).

73. Nathan C. Leites, *The operational code of the Politburo* (New York, 1951), xi, xiv.

74. Ibid., 13.

75. Ibid., 66.

seemed familiar. But their method of formulation and the institution from which they were promulgated lent them greater credence than Kennan's unsigned article commanded. Their implications were frightening. Certainly at RAND they served to inspire the institution's researchers to press on with their research and to bring any means they could to the conduct of the Cold War.[76]

Several scholars in addition to Leites brought major attention to RAND's studies of Soviet political thought. These included Herbert S. Dinerstein, whose *War and the Soviet Union: Nuclear weapons and the revolution in Soviet military and political thinking* (1959) and other works brought him his prestigious position at Johns Hopkins University's School for Advanced International Studies; Myron Rush, author of a penetrating study, *The rise of Khrushchev* (1958) and later chair of Soviet Studies at Cornell University; Philip Selznick, author of *The organizational weapon: A study of Bolshevik strategy and tactics* (1952); and Robert C. Tucker, whose books on Marxist political thought and action, beginning with *The Soviet political mind* (1963), raised him to the very height of acclaim as a distinguished professor at Princeton University.[77]

76. Mr. X [George F. Kennan], "The sources of Soviet conduct," *Foreign affairs, 25* (Jul 1947), 566–582. Diplomatic historians of the Cold War generally regard the X article as the catalyst for the formulation of the U.S.'s policy of "containment," a word that Kennan's article introduced into the diplomatic lexicon. Kennan's earlier "Long telegram," of course, also played a role. The U.S. policy of containment is embodied in NSC 68, which has now been published in a highly accessible volume edited by Ernest May, *American Cold War strategy: Interpreting NSC 68* (Boston, 1993). On the development of U.S. containment policy, see John Lewis Gaddis, *Strategies of containment: A critical appraisal of American national security policy* (New York, 1982). In the four years I have been carrying out research on RAND, I have yet to encounter a member of the institution's research staff from the 1950s who did not praise Leites and *The operational code of the Politburo* for their inspiration. Such praises are to be found in the Smithsonian Institution oral history interviews conducted under the Sloan Foundation grant and in interviews that David R. Jardini and I conducted with former RAND president Harry Rowen and Bruno Augenstein.

77. In addition to research on the Soviet Union's economy and politics, RAND during the 1950s pursued an extensive research program on machine translation of the Russian language into English. The motives for this research are obvious. RAND already carried out extensive translation work, both on technical subjects and military strategy. Machine translation was but one of the complex applications of computers that RAND pursued during the 1950s and early 1960s and involved many of the same problems that researchers working in artificial intelligence faced.

RAND's researchers carried out a large assortment of other Soviet-related research. The work of two non-Soviet specialist researchers should be noted, for it reflects how so much of RAND's research was shaped by the Cold War context of the "long twilight struggle" against the Soviet Union. Immediately after the Soviet Union launched Sputnik I and II in the fall of 1957, F.J. Krieger completed a comprehensive research report he entitled "Behind the Sputniks: A survey of Soviet space science," which appeared in 1958 as a book by that title published by the Public Affairs Press. Krieger specialized in rocketry, propellants, gas dynamics,

3. SOME WIDER INFLUENCES

This brief review of RAND's research from the 1940s to the early 1960s is far from complete. It highlights merely some of RAND's most significant research to provide a sense of RAND's range and to convey the spirit and context in which it was pursued. As this review has shown, RAND's researchers made fundamental contributions to several existing disciplines, opened up entirely new fields of human inquiry, and brought extant research disciplines together in ways that led to powerful new insights about a variety of phenomena.

Although RAND was supported principally by the Air Force from RAND's creation in 1946 until 1962 (the period under focus in this paper) and although RAND carried out an extensive amount of classified work for its "client," the knowledge that RAND generated was by no means localized within the defense establishment in general or the Air Force in particular. Owing to the historical moment in which RAND was created (at one of the high points of pure research ideology in the United States) and owing to the generosity of its principal patron, RAND developed a culture that not only prized independence but valued openness in terms of publishing its research findings. RAND became the paramount think tank of the Cold War era; it not only exercised considerable influence on its client, the U.S. Air Force, but also, through its development of systems analysis and the methods upon which such an approach drew, it helped to foster the pervasive quantification of the social sciences in the postwar era.

RAND and its researchers owed the authority they commanded to the power of numbers and scientific and technical analysis and to the stakes that the Air Force and indeed the entire nation came to place in such institutions and the "defense intellectuals," as they later became known, who inhabited them.[78] The research that RAND supported and its findings were continually shaped by the Cold War context in which the institution and its researchers were operating. With the Soviet Union seen as an enemy that could easily destroy the United States and its way of life, researchers were highly motivated to find ways to counter this threat. In doing so, they continually made assumptions that structured the problems they chose, shaped the way they approached and pursued their research problems, and

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and other areas related to astronautics, and he eventually left RAND to form his own consulting firm known as Planning Research Corporation. Arnold Kramish, a physicist known for his research on atomic bomb effects, kept both RAND and the Air Force apprised of Soviet atomic power developments through a series of research memoranda, which were eventually published as *Atomic energy in the Soviet Union* (Stanford, 1959).

78. Smith (ref. 7), does a particularly good job of articulating what he calls "the policy elite" and the "scientific basis" of their authority.

modulated the end products of their research.

The Cold War content of RAND's knowledge production and the biases of those that produced this knowledge were by no means apparent when RAND's success led to widespread emulation and its researchers migrated to copycat organizations and, more importantly, to research universities and governmental agencies. Historians of the Cold War era in the United States have recognized the influence of RAND's research and especially of RAND researchers in the so-called "McNamara revolution" at the Pentagon during the Kennedy and Johnson administrations (1961–1969).[79]

RAND's research, RAND's policy recommendations that flowed out of this research, and several of RAND's researchers played key roles in shaping the Kennedy campaign's position on defense, especially in promoting the trumped-up "missile gap" that helped Kennedy get elected by criticizing his opponent for being "soft on communism." Once elected, Kennedy made a pivotal choice of Ford Motor Company president Robert S. McNamara to head the Department of Defense (DoD). A veteran himself of the Army Air Force's Statistical Control Office out of which RAND had grown and sharing RAND's penchant for the objectivity of quantitative analysis, McNamara brought to the Pentagon a large number of RAND researchers to help him install the program-planning and budgeting-management methods that RAND's Economics Department had developed for its client (although the Air Force itself had rejected these methods) and to aid him in other dimensions of his DoD job.[80]

The consequences for the nation of this train of decisions about management of the Pentagon and the nation's foreign policy have long been debated. What has not been understood until now, however, is how these developments, coupled with the Office of the Secretary of Defense's growing support for RAND research that was often at odds with the Air Force, served to alienate RAND's creator and principal patron, the Air Force. That set in motion developments that would culminate in the Air Force's commitment to developing many of its own systems analysis capabilities largely independent of RAND and RAND's decision in 1966 to diversify its

79. The best, most recent account is Robert J. Leonard, "War as a 'simple economic problem': The rise of an economics of defense," in Craufurd D. Goodwin, ed., *Economics and national security: A history of their interaction*, annual supplement to Volume 23, *History of political economy* (Durham, 1991).

80. On the importance of the Army Air Force's Statistical Control Division to McNamara's approach to management, see David Loweel Hay,"Bomber businessmen: The Army Air Forces and the rise of statistical control" (Ph.D. diss., University of Nortre Dame, 1994) and John A. Byrne, *The whiz kids: Ten founding fathers of American business and the legacy they left us* (New York, 1993). On the movement of RAND researchers into the McNamara Pentagon, see Jardini (ref. 11).

research into domestic social welfare policy. Also not previously understood by historians of the Johnson administration's Great Society program is how RAND research veterans moved from the McNamara Pentagon into such administration offices as the Bureau of the Budget to install RAND methods and effectively to rein in out-of-control elements of the Great Society, especially its Community Action Programs.[81]

The perceived success of RAND in defense research and policy analysis led directly to the creation of the Urban Institute, which was not only modeled entirely on RAND but was also run for a long time by a RAND veteran. Only because of the actions of President Johnson's head of domestic policy, Joseph Califano, and his staff was RAND itself shut out of running the Urban Institute, which RAND's second president, Henry S. Rowen, thought he had secured before he had left the Bureau of the Budget to assume the presidency of RAND in 1966. Undeterred by the actions of Califano (of which he apparently knew nothing), Rowen pressed RAND into an ambitious program of domestic social welfare research. His efforts culminated in the formation of the New York City-RAND Institute in 1968, a venture promoted by New York's mayor John Lindsay "to assist [the] introduction into city agencies of the kind of streamlined, modern management thinking that Robert McNamara applied in the Pentagon with such success during the past seven years."[82] By the late 1960s, an increasing percent of RAND's budget went for domestic research, and the analytical methods, tools, and penchant for research that RAND had manifested at the height of the Cold War were actively engaged in the war on poverty.[83]

81. These new findings are a product of David Jardini's CMU doctoral dissertation research (ref. 11).

82. Quoted from "The Ford Foundation evaluation of the New York City-RAND Institute and its research to date" (5 Nov 1971), Gustave H. Shubert Papers, RAND Archives.

83. Domestic policy research expenditures at RAND would reach parity with national security research in the late 1970s. With the Reagan defense buildup in the 1980s, however, national security research at RAND would eventually rise to roughly eighty percent of RAND's budget. The end of the Cold War has brought about yet another change in the balance, with domestic policy research moving toward parity once again.