A RAND NOTE

Operations Research and Systems Analysis at RAND, 1948–1967

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By James Digby

The two decades covered by this account produced fundamental ideas about how to analyze big problems; they were also exciting and rewarding years for those who had come to the newly founded RAND Corporation. In 1950 the average age of RAND's professional staff was just under 30; most had been in the military or in support of a war effort for which there was almost universal backing. And it was a war effort in which many engineers, physicists, and mathematicians felt that their skills had made a major contribution not only to equipment design but to operational decisions.

While Thomas Edison had used statistical methods in advising the Navy on avoiding submarines in 1917, the widespread use of what came to be called operational research by the British came during World War II; scientists used statistical methods to advise on air defense, on antisubmarine warfare, on bombing and on many other operational matters.

In the United States, scientific advice was coordinated by the Office of Scientific Research and Development, and there were scientific advisors in many operational commands and in war industry. Some of these became senior figures in The RAND Corp.

One was Edwin W. Paxson, who had received a Ph.D. in mathematics from Caltech and worked on the training of pilots during the war. Among his talents was an ability to sketch word pictures which highlighted the main decisions of future operations. His RAND colleagues included former design engineers from aircraft companies, men who routinely used parametric relationships in the selection of wingspan, engine size, fuel loads, etc. Paxson put these parametric airplane designs into models of future operations, then formulated as output functions such variables as number of targets damaged. His goal was to select next-generation "atomic bombs and aircraft."

With vivid words, quick sketches, and color charts on poster board, Paxson would show how the various decisions impacted on expected results. The decisions he was most interested in were those which affected the size and nature of the next generation of bombers. It was Paxson who decided to label his study of Air Force choices "systems analysis."

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One problem that emerged as the early RAND studies were discussed was the absence of consistent data on costs. Some of the RAND economists, men who had been working under Charles Hitch on the economic effects of bombing, were critical of the bomber study's treatment of costs. The result was to bring the economists into the development of systems analysis. One such economist recruited for costing work was David Novick, who had come to RAND after extensive government service, to do industrial mobilization studies.

A push for air defense

Meanwhile, a new systems analysis project was being organized in 1949 and '50 to address what was widely regarded as a major national deficiency due to the post-war power and hostility displayed by the Soviet Union: the lack of an air defense of the United States. This project was headed by Edward J. Barlow, a radar engineer with wide-ranging interests. Barlow enlisted the help of dozens of RAND colleagues of many disciplines, organized into 37 projects. Each project was designed to produce results to fit into Barlow's master plan flow chart. Along the way his projects would select designs for fighters, ground-to-air missiles, radar networks, and other elements of an air defense system.

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Edwin W. Paxson

Charles Hitch

Edward J. Barlow

Each element was costed in terms of procurement cost and operating cost.

Barlow and his associates devised analytic relationships and map exercises to explore how various future systems would work. The study sought not only to advise on the choice of interceptors, missiles, and radar, but to calculate how wartime destruction would be affected by various investments in air defense. The project teams used parametric studies of fighters and missiles, and also invented and designed several needed weapons or systems. Several subsequent weapons systems—including the Army's Hawk, a method of tying radars together, some ways of rejecting ground clutter in airborne radar, and later the Genie nuclear air defense rocket—all resulted from these earlier studies.

The Air Defense Study considered four Soviet bomber types as possible threats: the TU-4 (a copy of the B-29), and three hypothetical designs. The hypothesis of Soviet bomber designs and future plans was taken even further by a "Red Team" approach led by Hans Heymann Jr., James DeHaven, and Richard Raymond. This synthesizing of a Soviet threat opened RAND analysis to considering what the Soviets might do, over a wide range of possibilities. But this approach was, in turn, criticized by Andrew Marshall and a former Air Force intelligence analyst, Joseph Loftus, who pointed out that much more could be inferred about a more realistic range of Soviet developments by looking at the actual evidence available on Soviet behavior.

A broader view of Soviet possibilities had also come from RAND's third major series of systems analyses, Albert Wohlstetter's Base Study and its successors. Wohlstetter, a mathematical logician, had come to RAND in 1951, after wartime work in quality control. His task, posed by the Air Force, was to analyze the critical factors affecting selection of bases for strategic bombers. He also was asked to apply his analysis to the basing of the 1956-61 SAC bomber force.

Early in this work Wohlstetter and his team saw that a critical factor was whether U.S. bombers would be knocked out by enemy attack before they took off on their mission—a factor that had been largely overlooked. They showed how devastating a small special-purpose attack on SAC could be and how little warning would be given, by comparison, with a massive over-the-pole all-purpose attack. Wohlstetter designed several relatively extreme cases to prove key practical points. By identifying *each* necessary step for SAC to execute its mission, he uncovered vulnerabilities that needed fixing.

While the SAC commander, General Curtis E. LeMay, did not adopt some of RAND's recommendations—overseas staging bases instead of intercontinental missions, and concrete bomber shelters, for example—SAC did move to decrease many of its vulnerabilities. RAND's systems analyses became widely regarded in defense circles as having important things to say about important decisions.

New ideas

As these systems analyses proceeded, it became clear to RAND management that the corporation was developing unique and important ideas in both strategy and methodology, and that these should be recorded and debated. An effort to synthesize these views on strategy was accomplished by the formation of a "1960 Committee," later to be called the "Strategic Objectives Committee."

Paxson's study had enlisted the services of Edward S. Quade and Robert Specht; both were mathematicians and both were consulted widely on methodological points. Paxson, Barlow and Wohlstetter were keenly aware that the validity of their major conclusions depended on sound methodology. Charles Hitch and John Williams, heads of the Economics Division and Mathematics Division, respectively, were strong advocates of improving RAND's methodology[1]. As a result, RAND's Management Committee asked Quade to put together a course in systems analysis sometime in the mid-1950s, a task for which he enlisted 14 of his colleagues. The resulting course, "An Appreciation of Analysis for Military Decisions", was first presented in 1955 to military officers and civilians associated with the military. The original course served as the basis for Quade's edited RAND book *Analysis for Military Decisions*, Rand McNally, 1964.

One offshoot of the Systems Analysis course was to stimulate Herman Kahn to shift his attention from phys-

Albert Wohlstetter

John Williams

Herman Kahn

ics to methodological problems. For a time, after giving a lecture and workshops in the course, Kahn planned a book on systems analysis and, with his assistant, Irwin Mann, published a book prospectus as RAND Research Memorandum RM-1829-1-PR, *Techniques of Systems Analysis*, June 1957. Kahn's book was never completed, because he instead devoted increasing attention to a series of lectures that led to *On Thermonuclear War*[2]. Along with other Kahn publications at the time, this volume provides a lively and useful insight into the practice of systems analysis at RAND in the mid-1950s[3].

Both the Quade course and Kahn's various pieces point up the way RAND's systems analyses drew on related methodological developments. Perhaps the most relevant was cost analysis. G.H. Fisher led the development of Project PROM, which made clear the distinctions between development costs, initial investment costs and operating costs, and presented total force structure costs. In addition to being a substantive development, PROM resulted in better display techniques, which conveyed convincing messages about the makeup of total force costs. This facilitated the development of program budgeting, which was essential for systems analysis and useful for other purposes, as well[4].

Other methodologies that were being developed at RAND also helped advance systems analysis. These methods included game theory—often of more help as an attitude than in direct applications[5]—linear programming[6], and dynamic programming[7].

RAND's pioneering work on digital computers complemented its development of systems analysis, though in the fifties the help from the "IBM Room," as it was called, was usually either straight-forward bookkeeping or analysis of a sub-problem (like the design of a missile wing).

A shift to broad issues

By the end of the 1950s RAND's work and reputation were well known among defense specialists and foreign policy analysts. Moreover, there was a substantial shift by senior RAND people from the analysis of fairly narrow decisions to the treatment of broader policy issues. The result was a number of important articles and books, as well as service by RAND staff members on important committees and commissions.

The first RAND book on systems analysis was R.N. McKean's *Efficiency in Government Through Systems Analysis* (John Wiley and Sons, 1958). McKean, an economist, kept his book at a fairly technical level. Another RAND book achieved a much wider audience: Bernard Brodie's *Strategy in the Missile Age* (Princeton University Press, 1958). While not a work on systems analysis, Brodie gave the field a friendly review in his chapter "Strategy Wears a Dollar Sign," pp. 358 ff. Brodie's book had been preceded a few months earlier by Albert Wohlstetter's often-cited article "The Delicate Balance of Terror," *Foreign Affairs*, January 1959, pp. 211-234, a direct offshoot of Wohlstetter's series of analyses.

Charles Hitch and Roland McKean's *The Economics of Defense in the Nuclear Age* was published in March 1960 and included some sophisticated advice for the systems analysis practitioner. It was followed a few months later by Kahn's *On Thermonuclear War*. Quade's *Analysis for Military Decisions* came out in 1964.[8]

Wohlstetter and several colleagues were invited in 1957 to brief the Gaither Committee, sponsored by the NSC. Later, they were invited to participate in the Surprise Attack Talks in Geneva. Henry Rowen was invited in 1959 to contribute a paper to an important Joint Economic Committee study[9]. Herman Kahn's lively (and lengthy) lectures had been given in many places. As the RAND analysts interacted at high levels of government, they realized that their studies had to be understood in broader contexts.

RAND goes governmental

But it was the advent of the Kennedy Administration in 1961 that brought both RAND people and systems analysis techniques into government. Hitch became Assistant Secretary of Defense (Comptroller) and Alain Enthoven joined him in that office. Henry Rowen became a Deputy Assistant Secretary for International Security Affairs. Later they were joined in the Pentagon by several of RAND's cost analysts. And as systems analysis became central to the office of the Secretary of Defense, Enthoven was made the first Assistant Secretary for Systems Analysis in 1964.

Robert S. McNamara decided that the systems analysis technique and more careful attention to the full cost

consequences of decisions was needed in NATO, as well. This led to establishment of a RAND analytic group at NATO headquarters, resulting later in the formation of a new Defense Planning Working Group and a Nuclear Planning Group, which required more careful analysis and costing. Under RAND's influence, abetted by the Norwegian and British delegations in particular, NATO made its first studies of crisis management and other studies which led to a flexible response strategy to replace the automatic nuclear response. The official adoption of the new strategy came in December 1967.

In sum, RAND's first two decades concentrated on the development and use of operational research and systems analysis to address problems of military strategy and defense policy. Also, during this period a foundation was established for extending this research style into such related fields as the size, structure and functioning of the Soviet economy, as well as more distantly related fields such as U.S. economic and military assistance programs, and such unrelated areas as the costs and performance of public education. These and other policy research areas became the focus of more extensive development of methods and applications in the subsequent 1968-1988 period. □

References

[1]In 1952 Lloyd Young, head of RAND's Electronics Division, and Igor Ansoff, Mathematics Division, had participated in the formation of the Operations Research Society of America. Young invited other RAND people to join. Hitch, assisted by Roland McKean and Andrew Marshall, prepared an invited paper for the first annual meeting of the society. See "Suboptimization in Operations Problems," *Journal of the Operations Research Society of America*, vol. 1, no. 3, May 1953. Herman Kahn and Andrew Marshall also presented a paper, "Methods of Reducing Sample Size in Monte Carlo Computations," at the same meeting. (Published in vol. 1, no. 5, November 1953.)

[2]Princeton University Press, 1960.

[3]The other publications, all cited in RM-1829-1-PR, are P-1165, P-1166, P-1167, and RM-1937.

[4]See David Novick, *Beginning of Military Cost Analysis 1950-1961*, RAND P-7425, March 1988, pp. 7-8

[5]"A primer on the theory of games of strategy" was published as *The Compleat Strategyst* by John Williams, McGraw Hill, 1954.

[6]George Danzig produced a series of RAND Research Memoranda between 1954 and 1958.

[7]See Richard Bellman, *Dynamic Programming*, Princeton University Press,1957.

[8]Regrettably, the founder of systems analysis at RAND, Edwin W. Paxson Jr., published largely in classified form. Because he liked to use specific examples involving nuclear weapon designs, most of his important early work was "Restricted Data" and has not been declassified.

[9]Henry Rowen, *National Security and the American Economy in the 1960s*, Joint Economic Committee, Congress of the United States, January 30, 1960.