RAND—A PERSONAL VIEW OF ITS HISTORY

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IT IS a happy coincidence that the OPERATIONS RESEARCH SOCIETY has invited a number of military operations-research organizations to devote a session of this meeting to view the past decade in retrospect. This fall Rand celebrates its tenth year of corporate existence, and we welcome this invitation to join our fellow organizations in this review and taking of stock.

Let me begin by reminding you briefly of some facts of our history. Conceived by General Hap Arnold, and originating, in part, in the Air Force's desire to help sustain the active interest of the nation's scientists in the problems of national defense, Project RAND was set up in March, 1946, by a contract with the Douglas Aircraft Company. General LeMay, then Deputy Chief of Staff for Research and Development, spelled out the mission of the organization:

> Project RAND is a continuing program of scientific study and research on the broad subject of air warfare with the object of recommending to the Air Force preferred methods, techniques, and instrumentalities for this purpose.

Today, Air Force Regulation 20-9, describing Project RAND's mission, reads a little differently. Since it is intended to give general information about Project RAND throughout the Air Force, AFR 20-9 elaborates on the original statement:

> Project RAND is a continuing program to assist the Air Force in improving its efficiency and effectiveness by furnishing information and independent, objective advice derived from selected research and analysis of airpower problems of interest to the Air Force.
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> To this end and in light of rapid advances in technology and expected changes in the national and international situation, studies, analyses, syntheses, and examinations in research, development, intelligence, operational, logistical, personnel, fiscal, electronic, and other appropriate areas are made to determine preferred methods, techniques, and instrumentalities that may assist in the formulation and implementation of Air Force plans, policies, and programs.

Douglas assigned some of its best men to form the nucleus of the new organization and went out of its way to make the new group feel at home. Still, Douglas found itself foster parent to an odd and, I am sure, often irritating offspring. Let's listen to RAND staff member and early settler,

JOHN WILLIAMS, as he describes some of the small problems that arose from this unprecedented marriage of the industrial and the academic:

> We had to all fit into the existing molds. And there were plenty of molds. For example, the Douglas Company—the whole aircraft industry for that matter—did not have a job description suitable for a philosopher. This problem was solved by taking the rate tables and using them backwards. You go down the rate table until you find the man's salary, and then you read across to find out what he is called. Well, that didn't bother us very much. But I think it's probably tainted the system for the next quarter of a century; if Northrop hires a man on the basis of a Douglas rating as a Design Specialist, they're likely to be surprised at what this man can and cannot do.
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> Our academic crowd had some peculiar problems in morale and public relations, from a personal point of view. If you met someone casually, as when traveling—a man who was friendly enough to identify himself as being from, say, United Shoe Machinery—it was only natural and polite for you to tell him where you came from; so you would say "Douglas Aircraft." The next question might be: "How's business?" Our philosopher, of course, knew nothing about how business was. If he was smart enough, he might try to dodge the issue and say, "Oh, I'm in Engineering." But this was usually the way to madness because probably the next question would be, "How's Ed Burton?" or something like that. If you didn't know Ed Burton, it was obvious you were a phony. In professional circles it was even worse. Academic people are like gypsies in some respects, so if you haven't seen a man for a few years, it is perfectly legitimate to ask, "Where are you now?" And just the bare statement, "Douglas Aircraft," is likely to be met with "How quaint!" Then, of course, he wants to know what you do there, and you say you do philosophy. . . . you can imagine the rest of it. This sounds humorous, but there was nothing humorous about it when you lived it.
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> The matter of hours of work were—and they still are—a substantial trial to academic people. Academic people have irregular habits, and have never taken kindly to the 8 to 5 routine. Well, we had one man who rarely showed up before two o'clock, and we had another who never went home. And, mind you, this was in an organization where they physically locked the doors at about quarter past five, and kept them locked until about ten minutes of eight in the morning. Well, they changed this for us, so that people could work nights and weekends. Not that we dropped it there; even now we try to work the 8 to 5 routine. In fact, I once wrote a memo "To All Concerned" (i.e., all the academic people) about how we should try to hold our end up on this 8 to 5 affair, that punctuality was one of the elements of training of the industrial side of RAND, and that it just didn't look good for us not to do better on it than we were doing. That memo had two effects. For about a week every member of the group who reached the building at 8 o'clock first came into my office to see if I was there. The second result was surprising: This memo was used as a club on the industrial workers throughout the parent organization, to try to shame them into coming to work at the time their unsophisticated academic colleagues assumed they came to work.

In order to start a library it was necessary for us to decide on and purchase a book. I was spokesman for several who thought it would be a good idea to start out with the *Britannica*. The response from Goldy (VICE PRESIDENT J. R. GOLDSTEIN) was, "What do you intend to do with it?" We ignored that for a moment and pointed out that he could probably get a second-hand one and that we'd prefer the Eleventh Edition or earlier—something published around 1910—because the technical content of the articles was much better in those days. Goldy responded that the Air Force wasn't interested in anything that happened before 1910, that RAND was a progressive organization and that we were supposed to be working on the future. Well, we got it somehow, and I think for our first year the *Britannica* and the *World Almanac* were our chief sources of intelligence.

We had a lot of trouble about blackboards. About the very concept of a blackboard in every office! I can remember CECIL WEIHE, our procurement chief, saying, "What's the matter with these people? Can't they write on paper?" Now this may sound as though I'm getting down to awfully fine details—but the chalk was worse than the blackboards. The company had no policy on blackboards, so we could get one in every office. But they did have a policy on chalk, stating that each blackboard could have two(or was it three?) pieces of chalk; and of course, our people wanted four colors. We had quite a flap on chalk.

Well, it was just little things like that. But as I say, as time went on this all straightened out. CECIL WEIHE in particular was a tower of strength in these matters. The day we asked him for a quart of paper clips his mask only slipped a little, long enough for him to say, "They don't come that way"; but a moment later he said, "Okay—but that's a hell of a lot of paper clips." We asked him for a quart of nails at the same time. After he found it didn't matter to us what size they were, he subsided; I don't think he has ever asked us another question; and in the course of the years he has requisitioned some curious things for us: He's gotten us twenty thousand ball bearings, the *Times* of London, the *Daily Racing Form*, and one pair of earmuffs.

To make clear the breadth of RAND's interests and to give assistance to Douglas in its guidance, the RAND Advisory Council was established. Concerned primarily with the broad direction of the new organization, the Council was made up of the Chairman of Boeing, the Presidents of Douglas, of North American, and of Northrop, and the Vice President for Engineering of Douglas.

RAND's first report carried the title *Preliminary Design of an Experimental World-circling Spaceship*—in other words, a satellite. Other studies during the first year concerned the design and comparison of rockets and ramjets, aerial refueling, the fabrication and use of titanium metal and alloys in supersonic vehicles (work done at Battelle Memorial Institute under subcontract to RAND), boron and other high-energy fuels (at Battelle), bomber and fighter design, air traffic control, high-energy radiation, air defense, nuclear propulsion, upper-atmosphere physics, and so on.

For two years Douglas operated Project RAND in the best interests of the Air Force and of the entire aircraft industry. After these two years of growth at Douglas, RAND had reached a point where it was desirable to set up an independent and permanent organization designed specifically to conduct research on problems of national security. Accordingly, in 1948 The Rand Corporation was formed, from whose Articles of Incorporation we read that this was to be

> . . . a nonprofit corporation . . . formed . . . to further and promote scientific, educational, and charitable purposes, all for the public welfare and security of the United States of America.

And, specifically, the Corporation, under contract to the Air Force, was to operate Project RAND.

The Corporation has been most fortunate in the high caliber of the men who have formed its Board of Trustees. The present Board is made up of men who at one or another time have held the following positions: AEC Commissioner; Chairman of the Ford Foundation; Chairman of the Pentagon's Research and Development Board; Deputy General Counsel of the AEC; Director of Brookhaven National Laboratory; Director of the Russian Institute of Columbia University; President of Battelle Memorial Institute; President of the Carnegie Corporation; President of the Carnegie Institution of Washington; President of the Columbia Broadcasting System; President of the California Institute of Technology; President of the University of Illinois; President of the Massachusetts Institute of Technology; President of Monsanto Chemical Company; Professor of Social Statistics, Princeton University; Trustee of the Carnegie Institution; Vice President for Engineering and Research of Westinghouse.

Project RAND's initial funding was a $10 million allocation from the Air Force. This was an amount adequate for several years of operation and was so designed by General Arnold to ensure the independence of the fledgling organization and its freedom from being called too early to exhibit its achievements. The Corporation had an additional financial problem: that of securing sufficient working capital. This problem was solved initially by a $100,000 interest-free loan from the Ford Foundation, which enabled Rand to establish a line of credit from the banks. The Ford Foundation later upped its loan to $1,000,000 and in 1952 the Foundation converted this loan into a grant under the condition that The Rand Corporation conduct out of its own funds an equal amount of "RAND-sponsored Research" on subjects in the national interest. That is, the loan was to be repaid not in cash but in research on problems of national security and public welfare that lay outside the scope of Project RAND's work for the Air Force.

The Air Force Project RAND was originally the Corporation's only concern and today is still its principal one. In addition, however, some research has been undertaken for other government agencies, such as the Atomic Energy Commission, when this promised to add to RAND's skills and to benefit both the agency and the Air Force. We have mentioned and will return again presently to the RAND-sponsored research that the Corporation carries on with its own funds. Finally, the Corporation has also undertaken some research for the Air Force that is of a more specific nature than Project RAND. Let's look at the most prominent example in this last category.

A small team of psychologists, working within Project RAND, set themselves the task of studying the way in which a group of men and machines work under stress. They chose an Air Defense Direction Center for detailed study and set up in their Systems Research Laboratory a simulated Air Defense Center, using junior college students for a guinea pig crew. None of these students had ever seen a real Direction Center; they had to be trained in their duties by letting them walk through, at accelerating rates, increasingly complicated problems involving 'hostile' raids superimposed on normal military and civilian air traffic. The crew was tested continually under gradually increasing stress, and the results were fed back immediately to the crew for study and evaluation and improvement of procedures. Air Defense Command officers were present to monitor the project; what sent them to long-distance telephones to call Headquarters, ADC, was observing these teenagers nonchalantly handling traffic loads considerably higher than the experienced crews of the real ADC Direction Centers were able to manage. What had been intended as research on patterns of behavior of men and machines working under stress had now produced a valuable method for training Air Force personnel.

The Air Defense Command asked RAND to exploit this technique and to set up a Systems Training Program. A separate group, the Systems Development Division, was set up within RAND to do the work of crew training. This Division soon acquired the additional jobs of writing computer programs for the various sites of the semiautomatic SAGE defense system (the master program was written at Lincoln Laboratory), and of developing training methods for crews of the SAGE system. As the job grew, the Systems Development Division became twice as large as the rest of RAND. On December 1, 1957, this Division was spun off as a separate and independent nonprofit organization, the System Development Corporation.

We have just seen that the Systems Development Division was, for a time, one of the Divisions within RAND. The present Divisions in which RAND's technical staff are organized are Economics, including the Depart-

ments of Cost Analysis, Economic Analysis, and Logistics; Engineering, including the Departments of Aeronautics, Electronics, and Operations; Mathematics, including the Departments of Mathematical Analysis and Numerical Analysis; Physics; and Social Science.

For the most part, these subdivisions are formed along lines of professional skills rather than by such categories of military operations as offense, defense, limited war, and the like. A minor advantage in this organization by skills is the assistance that it lends in recruiting the professional staff member. The major advantage is the flexibility of approach that obtains when no one group is given a monopoly on studies in a particular area—limited war, for example. This flexibility and competitiveness and some apparent looseness in organization in general are important assets in promoting an imaginative search for new ideas and new relations.

Air Force problems usually do not, of course, fall into such neat categories as economics or physics and, accordingly, our projects often cut across divisional lines. The same flexibility in organization, the importance of which we argued above, brings with it some problems in administration. The divisional officers must resist the natural tendencies toward parochialism and local loyalities and must value the contributions that their staff members make to projects headed by men from other Divisions. The scholar who contributes publishable research must learn to live in peace and mutual respect with his associate who does purely operations or 'project work.' If each man can mix theory and practice, can combine these two aspects within himself, so much the better. The scientist must learn to value his brother who merely invents the wheel without, at the same time, advancing the theory of that useful device.

These compartments into which RAND is organized are not to be taken too literally. On the Engineering Division roster one will find the occasional political scientist, astronomer, physiologist, or psychologist. The Mathematics Division is headed by an astronomer-mathematician and uses the skills of the sociologist and the philosopher. Mathematicians, in turn, have infiltrated most Divisions. In fact, it has been alleged that the Mathematics Division, far from desiring a monopoly of RAND mathematicians, feels that for another Division to hire a mathematician is to raise the cultural level of the Corporation. One of RAND's most impressive studies was headed by a physicist housed, appropriately enough, in the Physics Division, but a physicist who was offered a post in economics by one of our most distinguished universities. A project on Strategic Air Command operations may start in the Economics or the Social Science Division, one on limited war may start in the Mathematics or the Engineering Division, and so on. Such projects may start in these Divisions,

but once started they usually spread rapidly across divisional boundaries and involve men of many skills and from the several Divisions.

A project on SAC operations, we said, might start in the Economics or the Social Science Division. How do RAND studies start? A one-man project often starts with one man who has an idea, the usefulness of which he wishes to explore. That is, it is possible for someone to pick up a ball and run with it—as long as it is an inexpensive ball that he is running with. We can and must afford many small experiments of the one-man-off-in-a-corner type, small projects with little or no administrative review in their early stages. Many of these experiments die a-borning, others become productive projects and may either remain one-man ventures or may expand into larger and more expensive undertakings. In the latter case the problem of allocating our limited supply of manpower becomes a more difficult one, to be solved by the project leader, by the divisional administration, or by the RAND-wide administration. The administrator thus has not only the difficult task of administering research, but also the equally difficult and important task of sometimes refraining from administering. The search for a proper balance between too much order and organization and too little—this search is one that is unending and to which we are not to expect a simple and definitive conclusion.

Other projects come into being as substudies within the scope of some larger investigation. A study of the preservation of our deterrent force may give rise to a host of research studies ranging from the physics of ground shock to the statistics of enemy raid recognition. The Air Force also suggests problems as candidates for inclusion in the RAND program of research. Often these suggestions come by way of the RAND liaison representatives who are stationed in both Air Force and major command headquarters. These liaison scientists help the Air Force make best use of the RAND resources—and vice versa—and form one of the major chains of communication between RAND and the Air Force.

Another communication link between RAND and the Air Force is formed by the small group of senior Air Force officers who have a tour of duty in Santa Monica as members of our research staff. Dressed in the uniform of the day—sport shirt and slacks—they are not to be distinguished from their civilian colleagues. The presence of these imaginative officers who have had command, staff, and operational experience and who are working as members of the RAND team has added much to the usefulness of our product.

The Board of Trustees of The Rand Corporation meets twice a year, and a major share of each meeting is devoted to hearing and discussing the results of RAND research activities. Air Force General Officers invited to an early Board meeting were impressed with the interchange of informa-

tion and ideas and sought to make similar briefings available to key officers of the Air Staff. Accordingly, the 'MAG,' or Project RAND Military Advisory Group, was formed, which consisted of the Deputy Chief of Staff for Development, the Assistant Chief of Staff for Intelligence, and Officers at the Director level from Development Planning, Logistics Plans, Management Analysis, Operations, Plans, Requirements, and Research and Development; the Assistant for Operations Analysis meets with the MAG. Like the Board, the MAG meets twice each year for an intensive series of briefings and discussions; it then advises the Chief of Staff, U.S.A.F., on the Project RAND research program and on establishment of Air Force policy with respect to Project RAND. The MAG is an essential link in the chain of RAND—Air Force communications and an invaluable source of information, ideas, and wise advice to RAND.

The chief line of communication from RAND to the Air Force is made up of the briefings and publications by which we report on the results of our studies. At the informal end of the briefing scale we have the personal contacts between RAND men and their Air Force colleagues. These are less impressive but not less effective—perhaps they are more so—than the formal briefings that the project leader gives, at all levels in the Air Force, to those concerned with his study. Throughout the course of the project, the project leader has been given an unusual degree of autonomy in the planning and conduct of his project. At the conclusion of the study and after he has successfully run the gantlet of criticism from his RAND colleagues, the project leader himself carries his message to the customer in briefings to audiences ranging from *ad hoc* committees to the Air Staff of the Air Force, the Joint Chiefs, and the Secretary of Defense. In this reporting process, the scientist is never replaced by a stand-in, a 'briefer'; the man who has done the work is the man who talks to the decision makers. Both briefings and reports go not only to the Air Force but also to the Army, the Navy, and the Department of Defense, and to those contractors who have established a need-to-know for the classified technical information.

There is a lot of this information and not all of it is classified. In the decade that we are examining, RAND has distributed more than 300,000 copies of some 4000 Reports, Research Memoranda, Papers, and the like; about half of this output has been unclassified.

Unclassified results of RAND research are widely disseminated through limited free distribution, publication in scholarly journals and in commercially published books, and through our library deposits. About 1000 RAND publications may be found in each of forty Deposit Libraries (university and public) throughout the United States. The depository collections are growing and foreign Deposit Libraries are being set up. Some

500 university and public libraries have the 480-page *Index of Publications*, which lists the Deposit Libraries and all unclassified RAND publications; any library can borrow from the deposits. The publication figures given above do not include the depository collections: add another 40,000 copies.

Some thirty-one RAND books have been published to date; another four are in the publication mill, and three dozen more are threatening to enter the lists. A sampling of the published titles will indicate their scope: *Soviet Military Doctrine; Behind the Sputniks, A Survey of Soviet Space Science; Approximations for Digital Computers; The French Economy and the State; Weight-Strength Analysis of Aircraft Structures; Efficiency in Government through Systems Analysis; German Rearmament and Atomic War; Linear Programming and Economic Analysis; Labor Productivity in Soviet and American Industry; A Million Random Digits; Psychosis and Civilization; Strategic Surrender, The Politics of Victory and Defeat; Dynamic Programming; The Compleat Strategyst: Being a Primer on the Theory of Games of Strategy.* Translations have been made of some of these works into Russian, French, Swedish, Japanese, and Norwegian. On the other hand, one book, *Du malaise politique en France,* was first published in a French edition; a U.S. edition will follow. Books were not included in the publication figures given above: add 75,000 copies of our books that have been sold by commercial publishers.

These book titles give some indication of the variety of subjects that have occupied the attention of RAND staff members. The titles represent both work done for the Air Force under Project RAND and RAND-sponsored research projects financed from Corporation funds. Another clue to the scope and variety of RAND work is gotten from a quick sampling of Reports and Research Memoranda that have gone to the Air Force as products of Project RAND (listed in chronological order):

Aerodynamics, Gas Dynamics, and Heat Transfer Problems of a Satellite Rocket (February 1, 1947)

Titanium and Titanium-base Alloys (April 2, 1948; by Battelle Memorial Institute under subcontract to RAND)

A Decision Method for Elementary Algebra and Geometry

Fatigue Analysis of Aircraft Structures

Stalin and the Uses of Psychology

Communication Networks—1: Optimal Design and Utilization

Application of Dynamic Programming to the Airplane Minimum Time-to-climb Problem

Lunar Instrument Carrier: Attitude Stabilization

Weapon System Cost Methodology

Cost-Quantity Relationships in the Airframe Industry

A Revised Data-processing System for Managing War Reserve Stocks of Aircraft Spare Parts

Equilibrium Points in Games with Vector Payoffs
Electric Power Development in Mainland China: Prewar and Postwar
Notes on Linear Programming: Part XXXVI—The Allocation of Aircraft to Routes—An Example of Linear Programming Under Uncertain Demand
The Criticality and Some Potentialities of "Cavity Reactors"
Soviet Atomic Blackmail and the North Atlantic Alliance
A Recoverable Scientific Satellite
Experience with the Management-decision Simulation Game, Monopologs
Close-in Fallout
Studies in Machine Translation—2: Research Methodology

Now all of these Reports and Research Memoranda happen to be unclassified and available* at any Deposit Library. However, these unclassified publications give, just as well as would a short list of the classified ones, a picture of the scope of the studies made by Project RAND for the Air Force.

Any such list of titles must give an incomplete picture of our Air Force work. We should add projects on advanced chemical- and nuclear-powered aircraft and rockets; new logistics procedures; the cooling of high-speed re-entry bodies; the rate of growth of the Russian economy; the mutual interference of radar signals emitted by friendly radar and guidance equipment; changes in Soviet military thinking with the advent of thermonuclear weapons and ballistic missiles; the recovery of circumlunar rockets; new materials and structures such as titanium honeycomb sandwiches and metallic filaments, or 'whiskers'; Russia's trade-and-aid offensive in the cold war, including its venture into the field of international civil aviation; warning and defense against ballistic missiles; and so on.

This discussion of RAND publications points up a problem that faces any scientist or organization of scientists—that of keeping abreast of the bewildering flood of information and ideas that pours in ever-increasing volume from the world's laboratories. This problem is even more acute in an organization like RAND in which we try to avoid the compartmentalization of skills, where the physicist must know some political science, the political scientist must know some physics, and where a worker on one project may find stimulus for an idea coming from work in another and apparently unrelated project. The search for a proper balance between communicating and doing is another unending quest.

The majority of Rand studies and reports represent the Air Force Project RAND contract; a much smaller number concern the AEC and other contracts. And then there are the Rand-sponsored projects already mentioned, those financed from Corporation funds, that is to say, from

* With the exception of the first two publications on the list; these went out of print before the depositories were first set up.

the fees that we receive from our contractual work. The million-dollar grant from the Ford Foundation was, in effect, prepayment for research, and made it possible for Rand to use fee money for research much sooner than would otherwise have been possible.

Rand-sponsored projects have dealt with such subjects as the political and economic problems of Western Europe, U.S. economic and military assistance in Asia, political 'war gaming' of cold-war strategy and tactics, the economics of urban transportation and of water resources and their utilization, the use of systems analysis as an aid to governmental efficiency, nonmilitary defense, and the teaching of mathematics. These projects originate in the same way as do most of the Project RAND studies—some imaginative researcher conceives a problem that he wishes to tackle, that he feels is important, a problem that is not receiving adequate attention elsewhere or is one to which we may be able to bring new tools or a fresh outlook.

I thought a bit about inserting at this point an impressive list of inventions that RAND has made, of noteworthy points at which we have influenced Air Force policy, have solved Air Force problems, have made contributions to national security. I could take the cowardly way out and claim that the exigencies of military security prevent me from exhibiting this catalog of achievements, a catalog that I think you would indeed find impressive. Classified information is of course a problem. However, neither security nor a rare attack of modesty is the compelling reason that keeps me from parading this catalog before you.

The more one learns of the decision process in a military service, in the Department of Defense, in the Government, the better one learns that it is extremely difficult to assign credit uniquely for a success. It is not nearly so hard to count our failures. When we recommend one course of action and the world rides off in another direction, then we can chalk up an unambiguous loss—at least for the time being. On the other hand, when the world does take the route we have mapped out, it is seldom clear just how much credit is due us. Sometimes we have indeed been the prime mover; on other occasions our role has been that of the essential catalytic agent. For these reasons, then, you will find here no catalog of achievements. But this is an unprofitable investigation to pursue in any case.

RAND PERSONNEL now number about 800, with almost three-fifths of these forming the professional staff and representing a variety of skills ranging from the anthropologist to the statistician. Retired officers—Air Force, Army, Marine Corps, and Navy—add their experience to the staff.

Many RAND staff members do part-time teaching. Others have taken sabbatic leave to teach at Yale, Princeton, Harvard, the Sorbonne, The

Institute for International Studies at Geneva, to name a few; they have gone off to do research at the Institute for Advanced Study at Princeton, at the Center for Advanced Study in the Behavioral Sciences at Stanford, the Cowles Foundation, the London School of Economics, and so on. RAND men serve as editors or members of editorial boards of journals ranging from the *The Annals of Mathematical Statistics* to *Sociometry*. They serve on dozens of national and international committees and research bodies—for the IGY, the Department of Defense, the State Department, the Killian and Gaither Committees, and so on. Some are officers of professional societies: from the Council of the American Astronomical Society to the Board of Governors of the Middle East Institute. Rand does lack one aspect of university life: there are no thesis students to supervise. For one staff member, not even this difference exists; in some unaccountable way he seems to be supervising half a dozen Ph.D. theses scattered impartially over this country's universities.

Each Division differs from the others in its structure, its organization, the degree of direction exercised by the Division Chief, and its involvement in Rand-wide multidisciplinary projects. Each Division has its own character. For one Division the organization chart is an admirably complicated design with intricate lines of authority; for another the chart is simply a listing of names in alphabetical order. As far as I can see this diversity proves nothing other than that there are many organizational paths to the same goal.

What have we learned during the past decade? I have jotted down here some personal observations. But you will have to decide whether these are lessons learned or are merely prejudices of SPECHT; on this matter I cannot help you.

The past ten years have seen marked changes in our approach to systems analysis—that is, to analytic studies that deal with complex problems of choice in the face of uncertainty. Let me put the difference inaccurately but graphically: In our youth we looked more scientific; that is to say, we attached more importance, years ago, to the business of representing by a single analytical model that part of the real world with which we were dealing. With the context chosen, the assumptions determined, the criterion selected, we could turn our attention to the more intriguing questions of how best to apply modern mathematical techniques and high-speed computers to produce a neat solution from which conclusions and recommendations could be drawn.

Now there are many problems in the world for which this is a sensible, even a recommended, approach. There are problems impossible of solution without the use of the most powerful tools of mathematics and of computers. The optimal distribution of weight and thrust between the

several stages of a lunar probe, the determination of its initial trajectory—these are well-defined questions and yield to neat and orderly solution. On the other hand, the stability of the thermonuclear balance or the composition of a strategic deterrent force or the character of the next generation of tactical weapons—these are not questions that may be attacked usefully in this manner, although essential fragments of these problems may be solved analytically. A trivial reason for this is that even modern techniques of analysis are not sufficiently powerful to treat these problems without brutal simplification and idealization. The major reason, however, for the inadequacy of simple optimization procedures is the central role that uncertainty plays in this sinful but fascinating world. No longer are we analyzing a problem with a given and definite context and with specific equipment. We may not have clearly defined objectives. Instead, we must try to design—not analyze—a system that will operate satisfactorily, in some sense, under a variety of contingencies that may arise in a future that is seen only dimly.

This uncertainty that plagues us is not merely a statistical one—the fluctuations of a process that has a known probability distribution. It is the basic, the real, uncertainties about the future that are so much less tractable—uncertainties in objectives, in costs, in performance, in enemy reactions. As RAND staff member ALBERT WOHLSTETTER has pointed out:

> Recently some of my colleagues picked their way through the graveyard of early claims about various missiles and aircraft: their dates of availability, their costs, and their performance. These claims are seldom revisited or talked about: *De mortuis nil nisi bonum.* The errors were large and almost always in one direction. And the less we knew, the more hopeful we were. . . . For example, the estimated cost of one missile increased by a factor of over 50—from about $35,000 in 1949 to some $2 million in 1957.

The job of the systems analyst is not only analysis, but also design—to design a system that in the face of this real uncertainty, will operate well under a large variety of circumstances. Instead of merely analyzing a system for sensitivity to the major parameters, we must design the system to be insensitive.

We have learned that new tools—high-speed computers, war gaming, game theory, linear and dynamic programming, Monte Carlo, and others—often find important application and are often powerful aids to intuition and understanding. Nevertheless, we have learned to be more interested in the real world than in the idealized model that we prepare for analysis, more interested in the practical problem that demands solution than in the intellectual and mechanical gadgets that we use in the solution.

The statement that we now put less faith in the neat analytical ap-

proach to complex problems is not to be taken as an argument for non-scientific studies, for illogical arguments, or for seat-of-the-pants speculation. Detailed quantitative work of high quality is as important—in its place—as it ever was. The project leader must be able to defend his thesis, not by assertion but by logical analysis, against the questions of a hostile, but rational, audience.

It occurs to me that much of what I must say in this cliché-ridden account of 'lessons learned' will bear an unhappy resemblance to a stirring call to the defense of home and mother. The one thing, however, that gives me the confidence to impose these truisms on you is that we at RAND find it necessary to be reminded of them. If they are lessons learned, they are also lessons that we must learn and relearn again and again.

We have learned that the question of the realism of a study is a difficult problem, a problem that runs far deeper than the superficial aspects of rich detail or enormous complexity. We can easily design a study to be as detailed, as complicated as you like, and sometimes the temptation to do so is hard to resist. Such a study can be impressive, indeed; as Pooh-Bah said: "Merely corroborative detail, intended to give artistic verisimilitude to an otherwise bald and unconvincing narrative."

We must be careful, however, that our detail and complexity are compatible both with our knowledge of the real world and with the purposes of the study. Otherwise we run the risk of specifying a number in the third decimal place when we are ignorant of whether the whole number is positive or negative.

We have learned that while the world may be filled with practical people to whom any analysis is anathema, there is also too large a supply of those who have an exaggerated and unquestioning faith in the power of the analyst.

We have learned that the problem of maintaining a wise balance between basic and applied research, between long-range and short-range work is a difficult problem indeed. How much of our resources should we devote to responding to requests for crash jobs in the form of studies, comments on papers, proposals, information, briefings, conferences, and so on? How much should go into longer-range problems and how much into the blue? How much should go into replenishing our inventory of ideas and information from which we can draw to answer next year's crash requests? The answers to these questions tend to be elusive.

We have learned that a good organization must encourage independence of thought, must learn to live with its lone wolves and mavericks, and must tolerate the man who is a headache to the efficient administrator.

We have learned that it is possible for a far-sighted military service

to set up a research center in which civilian scientists can work with a high degree of freedom and informality; that the service can judge the research center by the value of its total output and not by examining prematurely each proposed project. We have learned that the administration of the research center can, in turn, afford similar freedom to the individual Divisions and to the individuals within the Divisions. We have learned that a research center need not follow any 'party line,' and that it will gain and hold the respect of its military service even though the two may sometimes be in sharp disagreement.

Let me close by reminding you that, as Rand staff member HERMAN KAHN says:

> Today systems analysts are getting to be both more modest about their claims and better at their work. If the trend continues, we may well come out with a match between claims and product.

OPERATIONS RESEARCH FOR THE SECRETARY OF DEFENSE AND THE JOINT CHIEFS OF STAFF

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THE Weapons Systems Evaluation Group (WSEG), as it is now constituted, is one of the newest of the military operations-research groups. For the benefit of those who are not familiar with the organization, I would like to take a few minutes to discuss how the organization has developed to its present form.

In 1947, after the enactment of the National Security Act, James Forrestal, the first Secretary of Defense, became aware of a void in the structure he had set up for the administration of the Defense Department. No provision had been made for a group to provide the Department of Defense with competent and independent scientific advice. The Secretary of Defense and the Joint Chiefs of Staff were completely dependent on technical advice generated for or by the separate Services. Since the recommendations received in this way were not always in agreement, and frequently totaled more than the available defense budget, the need for an independent technical review of sometimes incompatible recommendations was obvious.

The original Weapon Systems Evaluation Group was established to satisfy this need. The group was set up under a military director of three-