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15. J. M. Ziman, *Public Knowledge, The Social Dimension of Science* (Cambridge Univ. Press, Cambridge, 1968).
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Change in Argonne National Laboratory: A Case Study

The impact of altered management and objectives transform an AEC national laboratory.

Ann Mozley

For many years the American research and development community has been the envy of the world. Overseas researchers have flocked to it; presidents of all persuasions have endorsed it; and, most recently, President Nixon, noting the need to maintain the country's scientific leadership against challenging competition from abroad, reminded his electorate that "We support a strong program of research in the sciences with protection for the independence and integrity of participating individuals and institutions" (*1*, p. 145). The retreat from these goals and the crisis engendered in the scientific and engineering community by severe cuts in national funding have become the study of administrators, scientists, politicians, and sociologists. Their inquiries have been directed largely to the general climate of change (*2*). My study is an attempt to examine one major national scientific institution, the Argonne National Laboratory, Argonne, Illinois, in a context of organizational and national change and, from a review of its historical and contemporary situation, to offer a case study of the effects of altered administrative and conceptual objectives on a specific community of science.

The background data for the study was drawn from federal government reports and papers, annual and special reports from the Argonne Laboratory, and contractual and other documentary sources. The greater part of the evidence, however, was collected over a period of several months during 1970 and 1971 from informal interviews with personnel at Argonne—from division directors and associate directors, senior and associate scientists, administrators, short- and long-term scientists and engineers, to the Laboratory director, two former Laboratory directors, the vice president for programs and projects of the University of Chicago, and the president of the Argonne Universities Association. I thank all of them for their forthright cooperation.

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Origins and Early History

Argonne, a multiprogram national laboratory of the Atomic Energy Commission (*3*) for the pursuit of peaceful uses of atomic power, grew directly out of the wartime Metallurgical Laboratory of the Manhattan Engineer District based at the University of Chicago from January 1942. The first successful, controlled self-sustaining nuclear chain reaction (carried out under the direction of Enrico Fermi on a squash court of the University) was achieved in December 1942, and work was set for the construction of nuclear reactors for the production of plutonium, the process of separation and isolation of plutonium, and for related research in physics, chemistry, metallurgy, and biology. During 1944, the first heavy water–moderated reactor was placed in operation at an early Argonne site in Cook County Forest Preserve. After the federal government's plan to establish the Atomic Energy Commission under the Atomic Energy Act of 1946, Argonne was selected to become a principal, permanent, national laboratory devoted to research in the long-range development of atomic power, and was formally constituted on 1 July 1946. By formal agreement with the government on 31 October 1946

(*4*), the University of Chicago became operating contractor of the Laboratory, and Argonne was established on its present site in Du Page County, Illinois.

Despite the original plan for long-term basic research on atomic power, in January 1948 Argonne was assigned the role of principal reactor development center of the AEC with defined responsibilities for investigating the production of experimental, high flux, and breeder reactors and of advancing nuclear technology. Fundamental research on low energy neutron physics, the nuclear properties of isotopes, the chemical and physical properties of newly discovered or newly available elements, the effects of radiation on liquids, solids, and gases, and the biological effects of radiation were scheduled as part of the Laboratory's related basic research goals.

Period of High Productivity

In the field of nuclear reactor development, Argonne's small scientific and engineering teams faced a host of unknowns. A coolant system in which water, gas, and liquid metal were used as alternative heat transfer mechanisms had to be tested; vital data on nuclear constants and the behavior of metals under prolonged radiation were to be assessed; and pumps, control mechanisms, shields, and materials were to be developed and proved. Faced with the hazards of prototype experiments, the AEC acquired a former naval gun testing station near Arco, Idaho, as the National Reactor Testing Station in 1949. Throughout the 1950's, the nuclear reactor program conducted by Argonne in Idaho and Illinois centered on a high flux reactor, the prototype design and early development work on the U.S. Navy's submarine thermal reactor (STR) (*5*) for the *Nautilus*, the heavy water research reactors (CP-3 and CP-5), a series of boiling water experimental reactors (BORAX), the experimental boiling water breeder reactor (EBWR), supporting contributions to the Savannah River reactors, and the development of fast reactors for breeding and power. With a high proportion of scientific personnel engaged on the Navy reactor, the design and development of the first experimental breeder reactor (EBR-I) fell to a small group of engineering and scientific innovators at Idaho who, spurred on by the creative leadership of Argonne's first director, Walter Zinn, successfully demonstrated the breeding of plutonium from uranium-238 and the conversion of fission energy into electrical power (*6*).

In the following years Argonne went on to develop a variety of reactors for demonstration, breeding, and research—including the transient reactor test facility (TREAT); a fast test reactor; a succession of "zero power" research reactors; and the now major EBR-II which, designed originally as a prototype breeder and power plant, has become a leading facility in the United States for obtaining information on liquid metal–cooled fast breeder reactors. Argonne also initiated the development of mechanical and master-slave manipulators (mechanical hands) now widely used in nuclear industry, pioneered the development of nuclear instrumentation, and established research and development programs for studies of reactor safety.

At the same time, pioneering investigations on low energy neutron physics (which gave rise to a Nobel prize for work on the structure of the nucleus and to extended research on the shell model), the chemistry of the transuranium elements, isotopic substitutions in organic compounds, and metallurgy and materials nourished reactor technology and provided strong concentrations of basic research. A broad-based program of biological and medical research explored the biological effects of neutron and electromagnetic radiation (developing the first "iron room" for determining radiation in the human body and carrying on clinical studies at Argonne Cancer Research Hospital in conjunction with the University of Chicago) and led to radiobiological research in the application of atomic energy to medical biology and physiology. In high energy physics, expertise that was developed at Argonne on a 60-inch cyclotron in 1952 was substantially augmented by the design and construction of a 12.5-Gev zero gradient synchrotron (ZGS) beginning in 1959.

The original eight divisions at Argonne were physics, chemistry, metallurgy, reactor engineering, chemical engineering, instrument research and development, remote control engineering, and technical information. As needs changed, new and more complex problems evolved; these divisions proliferated, changed names and focus, amalgamated or fragmented into separate but cross-fertilizing divisions—including, variously, radiological physics, reactor physics, solid state science, applied mathematics, metallurgy, particle accelerator, materials science, reactor engineering, applied physics, reactor safety, and, by amendment of the AEC charter (1967), a center for environmental studies (*7*). Engineering and scientific personnel (585 in 1951, 621 in 1955, 1159 in 1966, and 1331 in 1971) were drawn predominantly from the universities and organized on an individual basis or in small cooperating groups. Under the successive directorships of Walter Zinn (1946–1956), Norman Hilberry (1956–1961), and Albert Crewe (1961–1966), each division developed its own measure of autonomy and flexibility within the defined interests of the AEC. External review committees in specific disciplines reporting to the University of Chicago evaluated programs and projects to ensure high standards of planning and research. Within this federation of divisions, the Laboratory director maintained a professionally close relation with his division directors and senior scientific staff. The role of the University of Chicago in operating the Laboratory was generally characterized as "free from interference" and "enlightened laissez-faire." The research divisions, offering considerable interdisciplinary contact, enjoyed an atmosphere of creative research. Two structural innovations in the 1950's—the establishment of an international school for nuclear sciences and engineering (1955), which offered advanced training for overseas scientists as part of the program of Atoms for Peace; and the appointment of an associate laboratory director for education to implement programs of graduate and undergraduate training from industrial, university, and government sources at home—emphasized the Laboratory's commitment to diffusing knowledge of nuclear technology and research.

By 1965, Argonne had established a unique international reputation in nuclear reactor and related fields. In "staff man-years," as the Joint Committee on Atomic Energy assessed the situation in 1960, the Laboratory had achieved a critical balance between basic and applied and developmental research, while its intellectual vigor and specialized equipment had yielded fundamental facts about atomic energy which were "the very heart of achievement in the nuclear field" (*8*, pp. 11 and 34). With the addition of one of the leading proton accelerators of the world, Argonne represented one of the country's centers of scientific excellence (*9*).

Role of the Universities

In October 1966, a tripartite contract signed by the AEC, the University of Chicago, and Argonne Universities Association initiated a new phase in Argonne affairs. As it is a major contributor of change, its antecedents should be understood.

Since the days of the Chicago Metallurgical Laboratory (MetLab), the idea of a national laboratory serving the interests both of government and of a regional group of universities was central to the thinking of the midwestern universities. It was widely held that Argonne should not be tied operationally to a single university, that its elaborate and expensive equipment should be equally available to the neighboring institutions, and that the universities which had helped plan the transition of the wartime MetLab to the status of a national laboratory should have a determining voice in its programs and policies. The contract signed with the University of Chicago in October 1946 dispelled these hopes, and the subscript offering cooperative research and a voice in the approval of programs initiated by the Laboratory and its operator was not considered an adequate expression of the universities' role. A self-appointed "Board of Governors of Argonne National Laboratory" and an ancillary Council of Participating Institutions, consisting of 24 midwestern universities (*10*), was constituted in 1946 to focus and articulate university goals.

At the outset two factors militated against the close participation of the universities in Argonne Laboratory affairs. The AEC, with a strong nuclear mission centered at Argonne (*11*), wished to avoid a commitment that threatened interference with their programmatic goal. Second, Argonne scientists, while welcoming assistance at the Laboratory from qualified university staff, were less willing to interrupt their researches to train the universities' younger staff members. The University of Chicago thereby gained the lion's share of collaborative programs of research, the total of which represented only 10 percent of Argonne's total basic research undertaking in 1950.

Despite obstacles, the universities persisted in their aims. The "operating policy of the Argonne National Laboratory" issued by the council of participating institutions in 1950 was approved by the AEC, and guarantees of interchange of personnel, the intake of graduate students at Argonne, and a mutual stimulation between Laboratory research and related university departments were secured.

The crucial thrust to closer university participation, however, came in the 1950's from the high energy physicists. Late in 1952, the midwestern universities group turned their attention to the pattern of national development in high energy physics which resulted in construction of a 2.5-Gev cosmotron at Brookhaven Laboratory on the East Coast in December 1952 and the scheduling of a 55-foot (radius) particle accelerator at the Lawrence Radiation Laboratory of the University of California in 1953. Marooned in the nonaccelerating heart of mid-America, the midwestern universities group planned a powerful accelerator of their own. Despite strong support for such a project from Walter Zinn, university physicists declined the suggestion of a cooperative venture at Argonne and, constituting themselves as the Midwestern Universities Research Association (MURA) in 1954, pressed the federal government for a MURA synchrotron to be built near the University of Wisconsin at Stoughton. Both AEC and Argonne objected to the plan. Zinn further opposed the compromise suggestion by the AEC that MURA operate a high energy particle accelerator sited at Argonne. A midcourse solution (precipitated by news of Russia's forthcoming 15-Gev machine) in 1955 proposing a crash program high energy accelerator at Argonne and a later "master" high intensity accelerator designed and funded by MURA brought Zinn's resignation as director in 1956 (*12*). A particle accelerator division was established at Argonne in 1958 under Albert Crewe, and the ZGS—one of the world's major atom smashers—was designed and built there from 1959 to 1963. MURA suffered the ultimate frustration when a presidential decision quashed the universities' dream for a powerful independent accelerator in December 1963.

Yet despite the failure of their own project, the accelerator question represented the thin side of the wedge in the universities' struggle for a significant participation in Argonne affairs. President Johnson marked the need for their presence in building the Laboratory into "the nucleus of one of the finest research centers in the world" in his now famous letter to Senator Humphrey of December 1963. The AEC favored only one national facility in the Midwest; and the Laboratory itself was ready to guarantee equal participation to the universities in the use of the ZGS. Nonetheless, throughout these years of discussion and negotiation, tension ran high (*13*). Neither Crewe (as director of the Laboratory from 1961) nor the University of Chicago were ready to capitulate to the full Midwestern plan. A proposal that Crewe submitted at the invitation of the University of Chicago in 1962 projecting the development of an Argonne graduate campus of the University of Chicago granting degrees in pure and applied science (*14*) provoked a storm and was hastily withdrawn by the president of the University of Chicago in the ensuing disarray. A modified proposal for an Argonne center granting postgraduate degrees from all participating universities did little to relieve the sense of strain. Nothing but a major say in Argonne policies (similar to the jurisdiction exercised by nine eastern universities in the operation of Brookhaven Laboratory) would now satisfy the scattered universities of the Midwest. An ad hoc committee comprising representatives of MURA, the Laboratory, and the University of Chicago, which was formed to discuss questions of high energy physics, extended their function to formulate larger plans. Their unanimous recommendations (trimmed down through several accommodations on the part of the Laboratory and the University of Chicago) for the universities' major share in the Laboratory management received AEC approval in October 1964 and were embodied in the founders agreement of June 1965. The Argonne Universities Association (AUA) (*15*), formed to represent the universities at the founders meeting became a principal party to the tripartite contract signed with the AEC and the University of Chicago on 31 October 1966.

It was a long haul from the abortive plans of the midwestern universities of 20 years before. The intervening years, moreover, had bred considerable discord in the relations between the universities and their laboratory peers. The faults were not all on one side. The universities' conviction that they had a lien on scientific talent was countered by the Laboratory's reluctance to associate them with research programs and an attitude of some reciprocal intolerance on the part of some Laboratory senior scientists. As the single operator, the University of Chicago had not extended itself under the terms of the signed contract to foster cooperative programs between its sister institutions and Argonne; and the

AEC, well satisfied with a single university operator, had convincing reason for wishing to maintain the informal relationship between the Laboratory and the neighboring universities. The outcome was a triumph for the university communities. The confrontation, however, had taken more man-hours, consumed more energy, and nourished more committees and conferences than many cared to admit.

Impact of Change

In assessing change at Argonne it is important to draw a distinction between the nature of change inherent in AEC laboratories—where, in the new fields of atomic energy, the balance of disciplines and organization constantly shifted to keep pace with scientific and technological advance—and the effect of pressures imposed from without. Between 1946 and 1966, Argonne experienced its due share of organizational evolution. By contrast, the changes that have arisen in the past 5 years find their origins largely in three external influences: (i) the advent of the AUA and a new directorate, (ii) the AEC's altered concept of Laboratory objectives mixed with changed national attitudes to science, and (iii) the specific modification of the nuclear reactor program implemented by the director for reactor development and technology of the AEC.

The tripartite contract of 1966 vested large nominal powers in the AUA: notably to formulate, approve, and review Laboratory policies and programs; to review and approve budgetary proposals and modifications; to establish policies for cooperative research and educational programs between the Laboratory and the scientific community; to approve (with AEC concurrence) the initial and continuing employment of the laboratory director and his deputy; and, in cooperation with the University of Chicago, to develop long-range objectives and programs for the Laboratory. For its part, the University of Chicago was charged with the task of cooperating with the AUA in the preparation and development of long-range plans for Argonne and of attracting and holding "high quality" scientific, engineering, and managerial manpower while it continued independently to manage and administer the Laboratory consonant with a dynamic and creative enterprise (*16*). The main missions of the Laboratory were conceived as basic research involving fundamental studies and theoretical and experimental investigations of interest to the atomic energy program and the conduct of applied, programmatic, and development work within the nuclear energy field.

One power the AUA was quickly called on to exercise was the appointment of a new director. Crewe, somewhat scarred by conflict, returned to a professorship of physics at the University of Chicago late in 1966. His successor Robert Duffield, a former associate professor of physics and chemistry at the University of Illinois, Urbana, with 8 years of industrial experience as manager of a gas-cooled reactor project, took office in November 1967.

The AUA and the New Directorate

"The language of the contract," the president of the AUA recently asserted, "is as it should be. How well we solve the problem is another matter." What is the record of the AUA in its first 5 years of office? From discussions with AUA's president and the Laboratory director, it appeared that both felt that AUA management had contributed significantly to Argonne's reputation and to its fruitful interaction with the universities. In the words of AUA's president, present management was "out in front" as an exemplar of a collaborative enterprise of laboratory and universities. This view was not widely endorsed at the Laboratory. Expressions of opinion from Argonne scientists ranged from observations like "Who are the AUA?" or "the AUA is a very shadowy body" to the judgment that the AUA has "not yet come into its powers." Others, more trenchantly, contended that the AUA has had "a deleterious effect" on Argonne and has acted as "a drag" and an "impediment" in some competitive fields. Many who viewed the AUA as an "impotent body" had little or no contact with its representatives. The more critical scientists tended to be associated directly with AUA management and collaborative work.

Two factors were influential in shaping the Laboratory scientists' view. Administratively the AUA is managed by a 19-member board of trustees (elected from the participating universities for a 2-year period) which meets about three times a year. The responsibility for advising the trustees on Laboratory programs rests primarily on seven board committees appointed in biology and medicine, high energy physics, physical sciences and mathematics, reactor development, environmental studies, education, and the budget, supplemented by the long-standing and eminent external divisional review committees formerly serving the University of Chicago and now reporting to the university and the AUA. As a result of this formalized structuring and the periodic nature of board committee reviews, AUA's managerial presence was, for the most part, scarcely felt by the Laboratory's scientific personnel. The areas of closest interaction involved high energy physics, where university faculty share 70 percent of user's time on the ZGS, and nuclear engineering where, through a joint educational committee of the Laboratory and the universities inherited from earlier times, advanced training courses, research-leave participation at the Laboratory for university scientists, and other collaborative activities are arranged. Other divisions which, since the 1950's, have enjoyed extensive collaboration and consultation with university colleagues through joint appointments, visiting faculty, and research associates, both inside and outside the Midwest, have found the pattern little altered by AUA management (*17*). The interaction, however, between the universities and Argonne in environmental studies, a new field of interest at the Laboratory which coincided with AUA management, and which AUA president Phillip N. Powers advances as a special instance of collaborative work, is not regarded favorably by Laboratory environmentalists.

The second influence stemmed from the discordant relations of precontractual times. The AUA, it was noticed, continued to describe the Laboratory as "a facility" (*18*) (a term not favored in contracts) and to think of Argonne as a place of service to its members where expensive scientific equipment could be shared. The emphasis of their long-term planning for basic research centered on large-scale equipment, the existence of large coordinated research teams, and the exclusion of small group and individually oriented projects that could be handled at universities.

It therefore appeared that a distant headquarters on Michigan Avenue, Chicago, a formal AUA liaison associate director, and the remote functions of the committees of the Board have not cemented a sense of shared aims and purposes between Laboratory scientists and the AUA. The AUA management,

indeed, preserved a strictly centralized point of contact with the Laboratory through the Laboratory director. Accordingly, many Laboratory scientists felt that AUA's detachment from the research interests and views of the Argonne staff seriously devalued their formulation of long-term plans for the Laboratory. They looked for closer consultation in the shaping of AUA policies. For his part, the president of AUA affirmed the AUA's specific interest in "what the Laboratory staff is thinking," but acknowledged that the line of communication ran directly through the Laboratory director.

Against this background of management, the style and objectives of Argonne's director assume a particular relevance. The tradition inherited by Dr. Duffield in 1966 derived from three components: (i) a strong encouragement of basic research that reached its high point under Albert Crewe, (ii) a direct interaction with the largely autonomous research divisions, and (iii) a sense of pride in Laboratory achievement and identification with its professional staff. Walter Zinn's administration was characterized by his active leadership in the development of nuclear reactor technology in which he was personally involved, that of Norman Hilberry (who assumed particular responsibility for the research divisions as deputy director under Zinn) by his open respect for Laboratory scientists and a conviction that the administration was there to serve the scientific personnel (*19*), and that of Crewe by his personal dedication to the growth of basic research.

From the outset, the present director set a different style. Coming from industry, he felt that much had become institutionalized at Argonne, that much was done on a continuing basis, and that, in a "placid" period of Argonne's development, there had been insufficient analysis as to "why." The Laboratory was, in his judgment, due for some scrutiny and change. He believed that methods of industrial management could be applied in this process to eliminate pockets of inexcellence, to cut dead wood, and to exert administrative pressure in order to keep standards of performance high. These methods encountered strong resistance from scientists accustomed to a large measure of independence in their work. They were resented for imparting a sense of insecurity, due to a looking over the shoulder or "keeping you on your toes" posture common in industrial management, but considered inconducive to creative research (*20*). Scientists who sought contact with the director found him not unsympathetic to basic research plans, but "passive" and given to advising that they seek support for declining research programs outside the AEC.

Senior scientists, some with more than 20 years of service, who had not had an opportunity to talk with the director felt real uncertainty about his outlook and complained of a serious communications gap. Younger scientists recruited both in the United States and overseas felt that their career choices were hampered by the lack of policy information of division projects and by the reluctance of the directorate to respond to requests for a ventilation of their concerns. They were critical of a technique of "keeping them on tenterhooks" and the loss of a sense of continuity on which their research plans hinged. A number of division directors found the director accessible, capable of quick decisions, and ready to lend an ear. They noted, however, that he kept a greater distance from the research divisions than any of his predecessors. The exceptions were the high energy physicists who, in a real sense, regard themselves as making up a third sector of an already dual Laboratory. Senior personnel there attested to considerable freedom of action inside the division and to the cooperative attitude of the Laboratory director. In general terms, however, Argonne scientists believed that the director's affiliations were with AUA and the University of Chicago rather than with the Laboratory, and that, in contrast to the previous administrations, he, his deputy, and his immediate associates had built up a private nexus of their own.

A major instance of the disparity between the scientific community and the director centered on the Argonne senate. The concept of an advisory group drawn from Laboratory senior and associate scientists and engineers and acting as a consultant body that could offer an expression of consensus on matters within their competence was first suggested by Argonne scientists before the signing of the tripartite agreement of 1966 as a method of relating the Laboratory's permanent scientific staff to the new management. On the assumption that this could best be done on an informal basis, a constitution was drawn up by the senate and ratified by the voting membership of senior scientific personnel which offered the senate as "a forum to conceive and to evaluate programs that are of potential interest to the Laboratory, and which will best meet the need of society." The senate interpreted its major purposes as encouraging the advancement of creative research and development programs, stimulating new endeavors, fostering improved communications within the Laboratory and with other institutions, expressing the considered opinions of the senate to the administration when appropriate on matters relating to the Laboratory's performance and operation, and advising and assisting the administration "as requested." Within this purview, the senate has to date successfully recommended the initiation of a Laboratory effort on practical aspects of controlled fusion and a study of possible bioengineering programs at the Laboratory.

However, despite senate (nonvoting) membership of the Laboratory director and formerly of the deputy director and of one other senior administrator as "contact points," the administration has not in general availed itself of an overture which, in the judgment of the senate executive committee, would put them in touch with opinion within the Laboratory and with informed evaluations of Laboratory research. A recent discussion between the senate executive committee, the Laboratory director, and the University of Chicago vice president of programs and projects on future plans and policies for the Laboratory, increased the senate's sense of disquiet. The Laboratory director has evinced little willingness to use the senate's advice. The University of Chicago vice president, in a blunt presentation of the administrative view, conveyed a contemptuous attitude to the scientists' concerns (*21*). The president of the AUA told the author that a consultative function for the senate could be of use, but insisted that the AUA is entirely guided in its relations with the senate by the Laboratory director.

Central to the concern of the senate executive committee is the status of the Laboratory's scientific personnel. As one member has written: "We function in a university milieu; our prime contractor is a university association and our operating contractor is a university. We consider ourselves as equivalent to university faculty members, our grades of Senior and Associate Scientist being assigned on the basis of equal professional stature to full and Associate Professor, respectively. Nevertheless we do not, as our faculty colleagues do, have any

voice in either self- or institutional governance" (*22*). Senate pressure for tenure, such as that enjoyed by the scientific staff at Brookhaven National Laboratory, has not been successful and the Argonne senate has thus remained a less authoritative body than similar organizations within the universities.

In this arena of conflict and criticism many acknowledge that the Laboratory director has a challenging task. His own motivations, as expressed to me, related to preserving "the best groups and individuals" at Argonne within the missions of the AEC, to bringing the proven methods of the physical sciences to the solution of society's problems, and to discouraging the military connections with Argonne research. His efforts to attain a fair representation of underprivileged minorities, such as blacks and women, have been categorized at the Laboratory as "affirmative action" and are now in force. His expressed belief was that "running a Laboratory means working with people."

Inevitably the question arises: Who selected the present director? According to the president of AUA he was the universities' choice. While no documentary evidence was available to me, opinions within the Laboratory veered from the conspiracy theory of history (with the deus ex machina appearing in different guises) to the straight judgment that the real, logical, and necessary arbiter was the AEC. The true story is doubtless more complex and remains to be told.

Altered Objectives of the AEC

One factor that has implicitly affected directorial policy and its impact on Laboratory personnel has been the shift in emphasis in Laboratory policy projected by the AEC. Despite the clear intention of the joint committee of 1960 to continue the multiprogram laboratories as "vital organizations . . . in basic research and development" and as principal sources for new scientific programs and fresh ideas, some discrepancy has developed between practice and policy. Sometime before federal government retrenchments under the Nixon Administration ushered in a period of severe research program cuts, the AEC was shaping a closer concentration of research programs at the Laboratory and a more relevant emphasis in some areas of development and research (*23*).

This concentration policy found expression both in internal changes in Argonne division leadership and in some major restructuring of divisions and groups. The tendency has been increasingly sharpened by budgetary reductions. Under these, nearly all the research divisions of the Laboratory have experienced staff curtailments and program cuts, and several suggest a growing disequilibrium between basic and task-oriented research. In essence the change has brought a shift away from individual and small-group organized work toward the formation of larger complexes for the prosecution of defined research work. The biological and medical research division of the Laboratory provides a methodological case in point. There, in a division once organized substantially on a basis of small groups and individual "scientific excellence," researchers have been rearranged around seven major research categories aimed to reflect the overall division mission of the AEC. While this has benefited some division members who now have additional assistants for their research, it has forced other senior and associate biologists into lines divorced from their original research concerns.

Other research divisions have met the programmatization in different ways. The division of chemistry, the largest division, has been the hardest hit. Significant staff reductions, program eliminations, and a marked emphasis on the task nature of the research has brought singular changes to the chemistry program which, in the opinion of some division members who have been at Argonne a long time, "challenges the headway that has been made." The problem of finding outside support to bolster shrinking programs is hindered here by the budgeting now being nationally applied in chemistry. Of all the research divisions, the long-term, well-reputed physics division has shown itself perhaps best fitted to weather the financial and administrative storm. Made up predominantly of long-range programs and long-service research personnel, the division has managed to retain much of its informal, small group, and individual structure and to preserve program flexibility through discriminating use of funds. Aware of an increasing age profile within the division, the division directorate aims to balance it by bringing in young scientific leadership and short-term scientific staff and contends that not all older investigators lose their creative power (a view not shared by the Laboratory's directorate) and that the presence of a number of independent researchers acts as a valuable catalyst for other staff.

Two of the divisions, applied mathematics and high energy physics, which are allied to low energy physics, face differing roles. In applied mathematics the pioneering work in computer building, image analysis, and analysis connected with large scale equipment for high energy physics constitutes a major contribution since the division's inception in 1956. Present administrative changes and contractions that suggest a diminution in the more fundamental fields of mathematics are regarded critically in the division and associated divisions as a short-sighted curtailment of the interdisciplinary role of the applied mathematics division. In the field of high energy physics, the future is characterized as "anyone's guess." Over $50 million of AEC money had been invested in the ZGS by 1970, and its research capability has been expanded by a 12-foot bubble chamber and the availability of four new secondary beams during 1970–1971. Yet the synchrotron at the National Acclerator Laboratory some 30 miles away at Weston, designed at its inception as a 200-Gev machine has already drawn off important staff from Argonne and, many contend, will render the 12.5-Gev ZGS obsolete in a matter of 2 to 10 years. While the Argonne high energy physics complex does not face the prospect of mission change, it confronts the more crucial problem of its potential future in a field of highly competitive funding of Big Science.

Apart from allowable particular differences in each division, the programmatic and "directed" research tendency at Argonne has stirred anxiety among scientific staff. There is concern, symptomatic of a national attitude, about AEC future planning for basic research, and uneasiness, in an institution geared to annual funding, about reestablishing the former balance between basic and programmatic work. Both the Laboratory director and his deputy, it is noted, come from applied research fields. There is concern that the expertise and experience developed over 25 years at Argonne may be lost. There is general consensus that the narrowing focus of research activity is "debilitating" to the institution and "destructive to the best interests of science." The applied divisions also feel the burden of closely directed research. "Group leaders," observed one member of applied physics, "have the job of completing a task, but little authority to

choose the task." At an individual level, scientists diverted into specific, often routine, research assignments have sought employment elsewhere; others find themselves trapped in uncongenial projects by present pressures of unemployment. The demoralization and the crisis in professional values is summed up in a popular lapel button which reads: "Argonne love it and/or leave it." While the budgetary figures do not reflect massive fiscal change (*24*), the implementation of cuts and modifications represents a far step from the joint committee's plea of 1960 for "continuity" and care in ensuring that shifts in emphasis in multiprogram laboratories give particular attention to their impact on the total health of the laboratory (*8*, p. 9).

AEC Nuclear Reactor Policy at Argonne

In 1965, the directorship of AEC's division of reactor development and technology passed to Milton Shaw. Five years earlier, the Joint Committee on Atomic Energy, reviewing the past era of productive reactor research and the mounting role of industry in taking over nuclear hardware projects, assessed the future of Argonne's reactor development in these terms: "Within the Laboratory's reactor development program itself, the emphasis will shift from large projects aimed at early achievement of competitive economic power from nuclear fuels, to longer range and more radical applications of nuclear reactors. This change will involve increased emphasis within the Laboratory on the general engineering research which is essential to furnish the foundations of the new technologies which will be required. . . . The fast breeder reactor as a source of power and of fissionable material will continue to occupy a significant part of the Laboratory's development effort throughout the decade" (*8*, p. 40).

Shaw's advent sharpened and transmuted these tendencies. His decision to place prime emphasis in the AEC's fast breeder reactor program on a new, complex, expensive, fast fuels test facility led in 1965 to the cancellation (just as construction was about to begin) of a more modest Argonne-designed fast reactor engineering (and fuels) test facility (FARET) which was scheduled for realization sometime in 1967, and to the contracting for the more radically designed fast fuels test facility (FFTF) with Battelle Memorial Institute (a nonprofit research organization) at its Pacific Northwest Laboratory. Then in 1967, Argonne's long-planned powerful neutron irradiation facility, the Argonne advanced research reactor (A^2R^2), was also abandoned by AEC.

The thrust of Argonne's experimental and developmental reactor work now turned on EBR-II, the liquid metal–cooled fast breeder reactor, originally considered as a demonstration reactor and now converted to a principal facility for irradiating fuels and metals to assist in the development of what the AEC espoused as the prime mission for the 1960's and 1970's—the production of high gain, fast breeder reactors for commercial use. A separate EBR-II organizational complex, upgraded and structured to consolidate related work in interdisciplinary fields, was created in 1968. A further large-scale restructuring aimed at consolidating the Laboratory's engineering development and supporting programs around a strong mission-oriented focus was carried out in December 1969. Central to the restructuring was a heavy concentration on administrative control exercised through an engineering research and development office directed by a new associate director of the Laboratory, presiding over the seven divisions participating in the nuclear reactor program and accompanied by the appointment of what Shaw described as "highly qualified and experienced full-time managers" (*25*).

Trends that now characterize Argonne's reactor program are a strong organizational structure framed to be wholly responsive to AEC and to what is described at the Laboratory as "Shaw's philosophy of design." This, in sum, denotes an emphasis on thorough quality assurance procedures that provide meticulous testing for all parts of ongoing reactor techniques and developments and supply the fixed codes and standards that earlier nuclear reactor technology neglected during the pressure of competitive experiment and design. At Laboratory level it entails the careful construction of all component parts before the whole is assembled, the repeated testing and recording of routine procedures, and a "space administration stress" on safety and quality control. Essentially it also entails a close and persistently documented overview of Laboratory performance by the AEC.

Reaction to altered missions and methodology at Argonne is precise. "Shaw's perfectionist philosophy," one senior administrator acknowledged, "can only be exercised when progress is not the main objective." There is criticism of the routine style of work of the "standards laboratory"; long-term reactor scientists believe that insistence on standards (while appropriate in mass production) is entirely out of place in experimental work; there is frustration among senior engineers at the exaggerated task basis of their work; and distinguished pioneers who were associated with the creative days of nuclear technology and who still remain at Argonne are not being utilized. In sharp contrast to the autonomous character of the Laboratory's early reactor work, those involved find the existing level of managerial accountability and the proliferation of paper work associated with bureaucracy an obstacle to constructive work. "A handbook of physics and chemistry," one reflected, "is now far less used than the AEC phone directory and the latest AEC organization chart." While this constraint has been most acutely felt in the division of reactor analysis and safety, it also bears directly on the complex problems inherent in the adaptation of EBR-II from a demonstration breeder reactor to the No. 1 fast reactor test facility of the nation. As a result, several long-term researchers and reactor builders have left Argonne. Others acknowledge strong misgivings about the outcome of present policy. Fundamentally, a significant sector of Argonne's qualified reactor personnel contend that the AEC division director's deployment of funding, overbearing management, and use or misuse of expertise at the Laboratory and in other AEC programs has put the U.S. breeder reactor development behind that of Britain, Euratom, and Russia by "5 to 20 years."

These fears are not dispelled by the present rate of reactor accomplishment in the AEC program. For example, the FFTF assigned to Battelle's Pacific Northwest Laboratory in 1965 was withdrawn early last year amid sharp charges from the AEC of delays in design and construction caused by Pacific Northwest's lack of "engineering-oriented organization" and "adequate management" and equally cryptic countercharges from Battelle at AEC "overmanagement" and the massive, often conflicting, daily directives from Shaw and his staff (*26*). It was subsequently transferred (now some years behind its original schedule) for completion and construction to Hanford, under contract to the Westinghouse subsidiary Wadco.

Reporting shortly before the transfer *Nucleonics Week* recorded (*27*) that "Shaw has felt for some time that he has not been getting a sufficiently forceful or aggressive effort from Argonne or from Battelle's Pacific Northwest Laboratory which has technical responsibility for the FFTF and where a management reorganization is expected also." The point, made frequently in interviews with Argonne staff who dealt directly with Milton Shaw, confirmed a tendency on the part of the AEC division director to shift responsibility for failure and delay. The point finds substance in Shaw's testimony at hearings of the Joint Committee on Atomic Energy (*28*) and on the fate of the LOFT (loss of flow test) facility at Idaho which also fell behind schedule under Shaw and has undergone major administrative changes as a result of the AEC's director's strictures on poor contractor management.

Despite AEC backing for their director and the caution issued by Representative Chet Holifield (D–Calif.) of the Joint Committee "not to block the quarterback" of the AEC's fast breeder reactor program (*29*), Shaw's policies and management are seriously challenged by those closely connected with reactor research. Argonne reactor scientists and engineers do not disguise their opinion that the Laboratory's apparent lack of vigor is due directly to the emasculating policies of Shaw as well as to inadequate technical capabilities of the division of reactor development and technology (DRDT) in its role of unchallenged decision-making.

"Part of the slowness in the last few years," Shaw has defended his own methods, "has resulted from an overprotective attitude, because this fast test reactor is vital to our future. . . . We have been proceeding quite deliberately and with extreme care" (*23*, p. 1401). His answer to the charge that the United States has fallen behind other countries in breeder reactor research rests, it is reported, on the claim that British and European technologies have yet to be fully proved. The Laboratory director, the University of Chicago vice president of projects and programs, and the president of the AUA give Shaw stout support. Considerable progress and strengthening, they believe, has been achieved. But, adds Powers, AUA's president and a professor of nuclear engineering himself, "If we are on the wrong track, we are in trouble."

Conclusions

Despite traditional opposition to change within an institution and the known reluctance of an "old guard" to accept new managerial policies and techniques, the reactions suggested in this study go well beyond the level of a basic resistance to change. The response, indeed, drawn from a random sampling of Laboratory scientific and engineering personnel, comes close to what Philip Handler has recently described as a run on the scientific bank in a period of depression (*1*, p. 146). It appears that Argonne's apprehension stems less from the financial cuts that have reduced staff and diminished programs by an annual 10 percent across the last 3 fiscal years than from the administrative and conceptual changes that have stamped the institution since 1966. Administratively, the advent of the AUA has not forged a sense of collaborative effort implicit in the founding negotiations or contributed noticeably to increasing standards of excellence at Argonne. The AUA has, in fact, yet to exercise the constructive powers vested in them by the contract of reviewing and formulating long-term policy on the research and reactor side. Additionally, the University of Chicago, once the single operator, appears to have forfeited some of the trust and understanding that characterized the Laboratory's attitude to it in former years. In a period of complex and sensitive management the present directorate at Argonne is seriously dissociated from a responsible spectrum of opinion within the Laboratory.

The crux of discontent among the creative scientific and engineering community appears to lie in a developed sense of being overadministered. In contrast to earlier periods, Argonne's professional staff feels a critical need for a voice in the formulation of Laboratory programs and policy. The Argonne senate could supply this mechanism. Slow to rally, their present concern springs from a firm conviction that the Laboratory is "withering on the vine." By contrast, the Laboratory director Powers, William B. Cannon, who is vice president of programs and projects of the University of Chicago, and a small selection of staff members believe that the Laboratory is going through a natural and inevitable process of change consonant with altered missions and objectives in an atomic energy laboratory. The general mood, however, demonstrates the Jeffersonian insight, as relevant in science as in politics, that only democratic governance provides salutary checks and balances when things go wrong. The point deserves close scrutiny when Argonne's tripartite contract comes up for renegotiation in October 1971.

Fundamentally Argonne's relations with its sponsoring agency remain at the center of its progress and future plans. Despite administrative and management changes, there is little doubt that he who pays the piper calls the tune. In common with other federal contract research and development adjuncts, Argonne has undoubtedly undergone tightening and winnowing away of flexibility in the past 6 years. In the nuclear reactor program the consequences have been strongly felt, and stringent national budgets have widened the tendency in the research domain. The impact of these changes and of AEC's attitude to basic research raise large questions for the future of the national laboratories. Few doubt that these "major national assets," with their outstanding scientific and technical personnel and equipment, fulfill a unique function and are here to stay, though their missions may undergo some change; the question of their most effective direction and handling, however, remains crucial for those concerned with priorities and decision-making for science.

A recent review of 40 national federal adjuncts (*30, 31*) has indicated that the primary sponsoring agency obtains better performance from a center that has a relatively high degree of independence than from one that is tightly controlled. The point is confirmed at Argonne where the present tendency (particularly on the nuclear reactor front) to use creative scientists as skilled technicians performing tasks specified in detail from Washington threatens to deprive the nation of the benefit of their scientific creativity and of their objective review and evaluation of AEC's programs. "The case for independence," Alan Pifer, president of Carnegie Corporation, has summed up the matter cogently, "rests on the simple proposition that for government to reap the real benefits that these organizations offer, they must be *genuinely* independent. If they are anything less than this, their effectiveness will be compromised. Among the benefits, as we have seen, can be a special capacity for experimentation, objectivity, the ability to recruit specially trained or talented personnel, flexibility, economy, and efficiency. Each

of these benefits is a direct function of the quality of the management of these organizations, and this in turn is a function of the degree of independence which management is accorded. In short, able men know that freedom of action is essential to their own highest performance, and they will demand it. Having won it, they will resist all attempts at government to erode it" (*30*).

References and Notes

1. Republican Platform 1968, quoted by P. Handler, "The federal government and the scientific community," *Science* **171**, 144 (1971).
2. A study sponsored by the National Science Foundation [J. G. Welles *et al., Contract Research and Development Adjuncts of Federal Agencies: An Exploratory Study of Forty Organizations* (Denver Research Institute, Denver, 1969)] explores general questions of the control, sponsorship, and future of the country's major federal contract research centers. See also P. Brown and C. Shepherd, "Factionalism and organizational change in a research laboratory," *Soc. Probl.* **34**, 235 (1956); P. Brown, "Bureaucracy in a government laboratory," *Institute of Industrial Relations*, reprint No. 36 (1954). (The last-mentioned offers an early case study of a single institution.)
3. Other Atomic Energy Commission multiprogram laboratories are the national laboratories at Brookhaven, Long Island, and Oak Ridge, Tennessee; the weapons development laboratories, Los Alamos Scientific Laboratory, New Mexico, and Lawrence Radiation Laboratory, Livermore; and the university laboratories, Ames Laboratory, Iowa, and the Lawrence Radiation Laboratory, Berkeley, California. For the official history of the Atomic Energy Commission and its laboratory growth see R. G. Hewlett and O. Anderson, Jr., *The New World, 1939–1946* (Pennsylvania State Univ. Press, University Park, 1962) and R. G. Hewlett and F. Duncan, *Atomic Shield, 1947–1952* (Pennsylvania State Univ. Press, University Park, 1969).
4. The original contract signed by the War Department was continued by the Atomic Energy Commission, which took official form in November 1946.
5. Argonne was assisted in this early work by Westinghouse Electric Corp. which then took over full responsibility for the light water moderator reactor program of the Department of the Navy.
6. EBR-I lit the small Idaho town of Arco for 1 hour in 1951. The EBR-I was designated a national landmark by President Johnson in 1966.
7. The list is not exhaustive; other nomenclatures may be found in the annual reports from the Argonne Laboratory.
8. United States Congress, Joint Committee on Atomic Energy, *The Future Role of the Atomic Energy Commission Laboratories* (Government Printing Office, Washington, D.C., 1960).
9. *Argonne Annual Report*, 1965.
10. In 1946 the participants included Battelle Memorial Institute, Carnegie Institute of Technology, Case School of Applied Science, University of Chicago, the University of Cincinnati, Illinois Institute of Technology, University of Illinois, University of Indiana, Iowa State College, University of Iowa, Mayo Foundation, Michigan State University, University of Michigan, University of Minnesota, University of Missouri, Northwestern University, University of Notre Dame, Ohio State Science, University of Pittsburgh, Purdue University, St. Louis University, Washington University, Western Reserve University, and University of Wisconsin.
11. There was, for example, no provision for university time-sharing in the use of Laboratory reactors.
12. Zinn based his objection on the ground that the imminent prospect of a superior MURA machine would prevent the recruitment of the best high energy physicists at Argonne.
13. The history of these troubled, often tortuous, relations between Argonne and the participating universities is the subject of a forthcoming book (L. Greenbaum, *A Special Interest. The Relationship between the Universities of the Midwest and Argonne National Laboratory* (Univ. of Michigan Press, Ann Arbor, in press). I thank Dr. Greenbaum for his information on several points.
14. The idea was not entirely new. The director of Oak Ridge Laboratory, Dr. Alvin Weinberg, had examined the possibility of converting the national laboratories into institutions like M.I.T. [*Science* **136**, 27 (1962)].
15. The geographical boundaries of this Association have subsequently been enlarged to include the University of Arizona, Pennsylvania State University, and University of Texas at Austin along with Kansas State University, University of Kansas, and Loyola, Marquette, and Wayne State Universities.
16. Contract W-31-109-Eng-38, supplement No. 16, clauses 5.3 and 5.4.
17. The physics division's tandem Van de Graaff accelerator, for example, has been heavily used by university scientists since its inception. The nuclear engineering educational committee has provided a particularly effective Laboratory-university linkage since 1956.
18. *Argonne Universities Annual Report*, 1970, p. 17.
19. Hilberry's evaluation was plainly illustrated in building management: the scientific and engineering staff inhabited the brick buildings, the administration, the old Nissen huts.
20. A. K. Smith has written of an earlier period in the history of the Metallurgical Laboratory in 1943, "there were an appreciable gulf between those accustomed to the directed efficiency of industrial research and those who throve in the more chaotic atmosphere of academic laboratories," in *A Peril and a Hope* (Univ. of Chicago Press, Chicago, 1965), p. 15.
21. In discussion with me, Cannon further challenged the representative nature of the Argonne senate and asked "If the scientists are members, why not the secretaries and janitors?"
22. Argonne National Laboratory Senate, *Bull. No. 18*, 27 April 1971.
23. While these trends do not appear to be publicly defined, the mechanism for their implementation is described in the evidence of the division of research given at the hearings before the Joint Committee on Atomic Energy, Congress of the United States, 91st Congress, 1971 (*AEC Authorizing Legislation Fiscal Year 1971*), March 1970, part 2, p. 573: "AEC influences the laboratories' level of effort . . . by indicating funding levels for each subcategory in the financial plans issued to the contractor. These financial plans are normally reviewed and revised several times during the course of the year. In addition, correspondence transmitted periodically to the contractor contains specific guidance regarding special selected items or activities. This type of guidance is also carried out more or less informally throughout the year through numerous meetings and discussions."
24. Physical and biological research funds from the AEC research budget for the fiscal year 1970–71 were $43.70 million; for 1971–72, $43.30 million. The real cuts, based on former growth expectations and inflationary trends, are in the region of 10 percent per annum for the last 3 years. In contrast, the essentially programmatic sector of nuclear engineering, funded by the separate development budget of AEC, $39,636 for 1970–71, has increased its expenditure over the past 5 years.
25. U.S. Congress, Hearings before the Joint Committee on Atomic Energy, 91st Congress, 2nd Session, 11 March 1970, part 3, p. 1401. The participating divisions are applied physics, reactor analysis and safety, chemical engineering, materials science, EBR-II project, the IMFBR program, and engineering and technology.
26. A letter dated 30 March 1970 from Battelle Memorial Institute to the General Accounting Office summed up the problem in these terms: "There is, in our overview, a burden of evidence that says DRD&T [Division of Reactor Development and Technology] overmanaged and Battelle (PNL) management overresponded—predictably—to these requests. To illustrate the over-supervision of DRD&T, for example, in a one-year period (July 1968–June 1969) 457 formal directives were received from DRD&T by PNL. In addition, 94 formal meetings were held between AEC and PNL staff. All of these directives, etc., were accepted by PNL in fact, if not in spirit"; U.S. General Accounting Office, report to the Congress by the Comptroller General of the United States, *Problems in Developing the Atomic Energy Commission's Fast Flux Test Facility* (Government Printing Office, Washington, D.C., 1970), appendix 1, p. 46.
27. *Nucleonics Week*, 18 December 1969.
28. See (*23*), pp. 1391 ff. and p. 1401; Laboratory views are nowhere represented in these submissions to Congress.
29. Speech, 3 December 1969, quoted in *Nucleonics Week*, 18 December 1969, p. 3.
30. See J. G. Welles *et al. Contract Research and Development Adjuncts of Federal Agencies: An Exploratory Study of Forty Organizations* (Denver Research Institute, Denver, 1969), chap. 7.
31. D. C. Coddington and J. G. Milliken, "Future of federal contract research centers," *Harvard Bus. Rev.*, March–April 1970, pp. 110–111.