Those early days
as we remember them
Part VII

Norman Hilberry, director of Argonne National Laboratory (seated) and Dean E. Dalquest (standing), superintendent of the laboratory's Graphic Arts division. They are examining an historic galvanometer recording of the fluctuation in a neutron density in Chicago Pile No. 1. The document, restored and framed in 1958, could be called a birth certificate of the atomic age.
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By Norman Hilberry
Argonne Director, 1956-1961
Associate, then Deputy Director, 1946-1956

My association with the nuclear energy business began with the kind of startling abruptness that was to become characteristic of the way in which so many of the Metallurgical Project staff joined — or, as some of them felt, were shanghied.

Returning home late on the evening of Saturday, December 20, 1941, from a New York University Faculty Club Christmas party, I found a telegram waiting for me. It said, “Need you for important war job. Please arrange immediate leave of absence and report to my office at earliest possible time.” It was signed “Arthur C.”

I rousted Martin D. Whitaker, my department chairman, out of bed early Sunday morning, read him the telegram, arranged the leave of absence, caught the Century at midmorning, and was in Compton’s office at The University of Chicago on Monday morning, December 22, 1941, almost as soon as he was. And from that moment my pattern of life changed. After 20 years of total immersion in university activities, I found myself plunged, literally overnight, into a new career, one in which my responsibilities suddenly shifted from those concerned with my own doing to those involved in getting others to do, and in ensuring that they were given the means for carrying out that doing with the fullest possible effectiveness.

Having just completed a thesis on extensive cosmic ray showers under Compton's aegis the previous year, I was under no illusions as I traveled westward that my services were wanted because of my scientific genius. "A.H." had long since established the fact that he personally possessed a supply of that ingredient fully adequate to meet any scientific or technological situation with which he was likely to be faced. Having had a broad experience in industrial research and development as well as in academic work, Compton was well aware that the task on which he was embarking would be a very major enterprise and would inevitably involve the kind of investigative teamwork that in those days was still rare in university activities, although increasingly prevalent in industrial operations.

The character of much of the research and development work that had to be undertaken was such that essentially only members of the university research community possessed the scientific background vital to formulating and carrying out the necessary R&D programs with the sure ness and speed that the crucial nature of the project made imperative. And by far the largest majority of these qualified investigators were certain to be individualists who could be fully effective only in a working environment that simulated that to which they were accustomed.

Compton's problem in the present instance, was that of finding an administrative mechanism that would provide the freedom of individual action that constitutes the strength of university research in both its originality and productivity, while at the same time ensuring that the results so obtained would mesh together as well as if accomplished under the more tightly coordinated industrial operating structure.

The obvious answer was to so centralize the R&D activities that all concerned would be in essentially continuous, intimate personal contact. With sufficiently general work assignments and sufficiently broad potential overlap in the assignments to the different R&D groups, competitive professional drive would provide the best assurance obtainable that wide scientific and technological consideration would be brought to bear on the Project's problems and that all results would be subjected to the most critical evaluation that could be hoped for.

To achieve such a working environment clearly demanded the establishment of a centralized R&D organization devoted exclusively to the Project's problems. This course of action was further supported by the fact that only in this way could the Project satisfy the imperative need for an absolute secrecy barrier between its activities and the outside world, while simultaneously maintaining that freedom in internal information flow that is essential, at least at the upper scientific and technological personnel levels, for effective prosecution of research and frontier development activities.

Having explored the possibilities of taking over some established industrial R&D laboratory as a going operation which could then be modified and expanded as the situation required, and having further found that any industrial laboratory that could serve this purpose was already fully occupied with essential war work, Compton decided that he had no choice but to set up his own organization essentially from scratch.

This is where I came in. I had known "A.H." for nearly 20 years. This long-established friendship had expanded into a close-working relationship as well in the period immediately preceding the initiation of the Project. At Compton's request I had taken an active part in organizing and carrying out cosmic ray research expeditions to Mt. Evans, Colorado, in the summers of 1939 and 1940. In the summer of 1941 I had helped organize and carry on The University of Chicago-U.S. State Department "Good Will" Cosmic Ray Research Expedition to South America which Compton had arranged and in which he took an active part. Although largely a matter of understanding rather than of explicit designation, my role in each case was fundamentally that of a general utility field aide to Compton himself. The arrangement worked, the expeditions were successful despite the unexpected difficulties to which such enterprises are always subject, and consequently, when A. H. accepted responsibility for the Project, I was recalled to serve in the new enterprise as I had in the past on the expeditions. Thus I found myself plunged into all of the headaches involved in building an organization and in getting it functioning effectively and in high gear on a desperately tight time schedule.

The objective, the task

January 3-4, 1942, witnessed the first official meeting of those whose research on the fission process had eventually led to the establishment of what would henceforth be called the Metallurgical Project. The Project's work assignment had been firmed up. Essentially it was to carry out all of the research, development, and associated activities needed to ensure the production of plutonium-239 in quantities of military significance.

Basically this would accomplish two objectives: 1) It would furnish, for whatever help it might provide, the basic experimental data on the slow neutron chain reaction as a precursor to the fast neutron chain reaction studies required for the nuclear weapons work. In addition, if successful, it would 2) provide an alternate fissionable material that could be obtained by neutron irradiation and chemical separation methods, thus avoiding the enormous difficulties inherent in the isotope separation processes required to produce uranium-235 sufficiently free from uranium-238 to serve weapons purposes.

To achieve these objectives, however, would be no small matter. First it would be necessary to establish a controlled, selfsustaining nuclear chain reaction using normal uranium. This seemed a probability, were sufficient heavy water available — tons of it — to serve as the moderator; and a possibility if enough graphite of sufficiently high purity could be obtained. To get the heavy water would require a major isotope separation operation and, while a much less difficult task than the separation of the uranium isotopes, it would still be a slow business to produce adequate quantities. So graphite seemed the best hope for an early achievement, and it was made the prime choice for the Metallurgical Project work. Heavy water production was recommended to the national project authorities as a vitally important backup moderator, and the recommendation was implemented, but for the Metallurgical Project, graphite had to be the choice.

Once the nuclear chain reaction was achieved there would be the tremendous engineering development task of designing a reactor that would operate successfully at the relatively enormous power levels that would be required to generate militarily significant quantities of plutonium. In the proposed scheme, the plutonium would be generated in the same normal uranium that served to establish and maintain the nuclear chain reaction. A completely artificial element, it would perforce be generated one atom at a time as a uranium-238 atom captured a neutron from the flux produced by the nuclear chain reaction and then transmuted into plutonium by spontaneous radioactive transformation. One atom at a time, with many kilograms required to achieve military significance, meant that a fantastic neutron flux in the nuclear reactor would be essential. But for every two neutrons, approximately, in that reactor flux, one fission event with its relatively enormous energy release must have taken place.

From the first, therefore, the goal was the construction and operation of a nuclear reactor with a capability of operating at a power level of the order of a million kilowatts. This would produce plutonium at the rate of something like the kilogram a day needed to make the operation of very real military significance. For the present purpose the important fact is that this proposed power level was 10 times that of the then-existing average big electric power generating station, so that the straightforward engineering development problems involved, while not insuperable, were nonetheless clearly very considerable.

But success even to this point would not get the project out of the woods. To get a nuclear reactor capable of operating at a production rate of a kilogram a day was going to require a large quantity of normal uranium fuel not only to achieve criticality but also to provide adequate heat transfer surface in order to keep the fuel temperature within a feasible operating range. Something of the order of at least a hundred tons seemed to be a fair guess as a minimum quantity. With a ton being roughly a million grams, this would mean that each day the one thousand grams of plutonium produced would be imbedded in the matrix of some one hundred million grams of normal uranium. While not uniformly distributed in the uranium loading, it would still be true that the plutonium produced in a day’s operation would constitute an impurity in the uranium present in some tens of parts per million. Thus on any feasible production run, the plutonium to be recovered from the irradiated uranium would be present only to a small fraction of a percent.

To make the situation even more challenging, for each plutonium atom produced at least two highly radioactive fission fragment atoms would also be formed within the uranium, so that any chemical separation of the plutonium, from this now complex matrix in which it was embedded, would have to be carried out by remote control methods in the presence of an intense radiation field. And in addition, for the process to be acceptable under the militarily useful criterion, the recovery of the plutonium would have to be essentially complete.

That the development of such a process for a well known and thoroughly studied chemical element would be enormously difficult goes without saying. In this case the enormousness was compounded in multifold fashion by the fact that up to that time the world’s supply of plutonium was counted in atoms. In consequence, except for its fission characteristics and the sketchy chemical information gained in carrying out the carrier separation of these atoms from the irradiated matrix in which they were formed, there were no experimental data on the physical and chemical properties of plutonium. Moreover, save for the microgram quantities that could be produced through irradiation of large quantities of uranyl nitrate by neutrons being produced by around-the-clock operation of several cyclotrons, for some time to come there would be no plutonium with which to experiment. And yet, if the second objective were to be achieved successfully it was imperative that a chemical separation process be developed speedily and that the necessary chemical separation facilities be built in time to process the uranium loadings of the reactors as soon as the irradiation process in them had formed a feasibly recoverable quantity of plutonium.

Complicating the whole plutonium production process was the fact that it would require operations involving levels of radiation and quantities of intensely radioactive materials that previously would have been completely unimaginable. This not only called for a comprehensive program of shielding and containment research and development activities, it required in addition an intensive review of the field of radiation biology and medicine and the initiation of an all-out research program on the interactions of radiation and radioactive materials with biological systems of all kinds. Only to the extent that this program led the way could the requisite measures be taken that would ensure the health and safety of the operating personnel and of that segment of the public that might live or work within the region of potential influence of the proposed operations.

These then were the tasks that faced the Metallurgical Project as the first meeting of the Project staff convened in the conference room of Eckhart Hall on that January 3, 1942.

“Time was our basic currency”

The colossal nature of the above tasks, however, gives but one facet of the situation the Project faced that first Saturday in 1942. The world situation and our national position in it provided a psychological environment that pervaded every Project activity and weighed continually on every staff member right up to the final surrender of the German forces. Nearly three years had passed since the announcement of the discovery of fission and the publication of the fact that each fission event was accompanied by the release of something more than two neutrons on the average. The U.S. investigators had attempted to have this discovery held in secrecy but the French refused and published their results; the U.S. teams then reluctantly published theirs.

It was then evident to scientists everywhere that a nuclear chain reaction might be possible. With the German scientists ranking among the world’s leaders in this field, it was simply inconceivable that they were unaware of the possibility of establishing a nuclear chain reaction and of all of the implications of that fact, including the possibilities of constructing enormously powerful nuclear weapons. Evidence from visits to German laboratories, after World War II started but while U.S. citizens were still being welcomed, convinced the visitors that neutron research of the chain reaction type was being actively pursued. If so, this could well mean that the German effort might be as much as eighteen months to two years ahead of our own.

Several other possibilities were equally clear. If Hitler had any inkling of the military potentialities, it was inconceivable that he would not push his scientists and his industrialists to the limit to get such a weapon at the earliest possible moment. That German science and industry were entirely capable of carrying such a project to a successful conclusion, we had no doubt. Their total engagement in the war might slow them up, but many, at least, of the Project staff simply could not "believe that Germany was not already well along on the path to a nuclear weapon before we really got started. Hitler’s occasional hints about his secret weapon did nothing to allay our fears.

And it was obvious that if Hitler laid his hands on such a device first it would be used without scruple in its most devastating fashion. Defeat for us as well as the rest of the nonfascist world would be inescapable. No major holiday of the Allied world approached without our holding our breath as to whether or not this would mark the unveiling of the nuclear bomb, for Hitler’s penchant for using such occasions as a proper time to spring his surprises was well known.

This sort of universal belief on the part of the Project staff that national survival itself was the stake for which we were working and the corollary belief that therefore time was of the imperative essence tided the Project over the host of organizational and operational shoals upon which it would otherwise most certainly have foundered. Characteristic of the feeling is the wail with which I was occasionally assailed by one of my best friends when some requested action was delayed for 24 hours: "Damn it, Hilberry, is the Project office going to insist on losing this war?" Fear of national catastrophe should we fail, or fail to achieve in time, was the constant companion of the most of us. Time was our only basic currency.

These were the tasks and this the conviction of urgent necessity as the Project staff from all of the participating research groups gathered on January 3, 1942, to plan the Project work programs under the new OSRD sponsorship.

Assets and deficiencies

What were the Project's assets? There were essentially only two, but both were of high value. The second of the two, without which the first would have been helpless, was the backing for an all-out effort by the highest Washington command, and its conviction of the absolute necessity that such an effort be made. With such support guaranteed, the Project's first asset was comprised of the men who were gathered there in that soon to become familiar Eckhart conference room. They, their research and development skills, their unique knowledge and understanding of the nuclear fission field in particular and of the broad range of physics in general, and their total conviction as to the imperative and urgent necessity for swift achievement of the envisioned goals constituted without question the Project's greatest, if not indeed its only, parochial asset. It was a necessary, but a far from sufficient, condition for successful accomplishment.

Which, of course brings up the question, not of the Project's liabilities — of which, it is true, there were a few — but more importantly of its deficiencies, of which there were a multitude.

The first set of deficiencies were those associated with staffing. Except for the California plutonium group, who were chemists as well as physicists, essentially the entire group of investigators associated with the project work at the start were physicists. This was natural and indeed up to this point proper because, unless it could be shown that a controlled, selfsustaining nuclear chain reaction was indeed a scientific reality, effort expended on the other tasks would be unjustified. On the other hand, as soon as the probabilities of establishing a nuclear chain reaction began to look more promising than questionable, it would be imperative to put full steam ahead on all of the other Project tasks as well, for many of them could prove to be even more difficult and timeconsuming than the chain reaction studies themselves. This would be markedly true of the biological and medical studies, and could prove to be so for the chemical studies as well. Even the chain reaction physics studies were then staffed at a university research level rather than on the basis of facing a crucial national emergency. And as the meeting progressed from Saturday on into Sunday, it seemed increasingly obvious that, given the purer uranium and graphite with which it should be possible to produce industrially in industrial quantities, the chances for establishing a controlled self-sustaining nuclear chain reaction were shifting from the possible to the probable.

"We were completely unprepared"

The time had come to get the project into high gear on all fronts. But how? It not only lacked staff in disciplinary variety, it had no facilities in which to house them or the essential equipment required to make their research and development ef forts effective. It likewise had no experienced body of skilled technological services to support the investigative work, and no team of administrative personnel who were accustomed to the idiosyncracies of research and development work and of the practitioners thereof.

In fact, faced with the probability that an enemy was well on the way to a scientific and technological breakthrough that would result in giving him such an overwhelming military superiority that our sole choice would be to choose between complete societal destruction or the acceptance of military defeat and the endurance of political subjugation for generations, the United States found itself disastrously unprepared to take effective scientific and technological counteraction. We were so completely unprepared in terms of communication between the scientific community and the government that the better part of two years had been lost, and if it had not been for the bridge established by Bush and Conant the time gap could have been much longer.

We were also unprepared in terms of having adequate national scientific and technological establishments properly staffed, organized and equipped to carry on effective research and development activities in essentially any area of scientific or technological crisis that might face the nation.

It might be complained that the nation was obviously well enough prepared because we did in fact win out and did produce the atom bomb and do it first. This would be subscribing to a fatal form of wishful thinking. We won, it is true, but it was German failure that ensured our victory, not the excellence of our preparedness. And another time our adversary — whether Mother Nature, societal change or military adversary — might well prove to be less accommodating in committing errors in our favor.

From 40 to five thousand

Obviously, it is beyond the scope of this note to trace the step by sometimes agonized step by which the 40 or so members of the Metallurgical Project in March, 1942, grew to encompass the Met Lab, Clinton Labs, the Ames Lab, the research groups at Berkeley, Battelle and MIT, plus numerous other groups with at one time more than 5,000 employees all told. In disciplines the physicists were joined almost immediately by the chemists, who burgeoned, and by the engineers, who multiplied somewhat less spectacularly. By July 1942 the biomedical work was in full swing, and in August both metallurgists and chemical engineers joined the force. Here indeed was a true interdisciplinary operation. And team activity grew as the work progressed, both within and between groups, so that by the fall of 1944 the Metallurgical Project had developed precisely the sort of research and development establishment that would have done so much to expedite the Project's tasks had it existed in perhaps a somewhat less expanded but readily expandable form in January 1942. And with this organizational achievement accomplished, the tasks on which the Project had been fully engaged approached completion.

Job finished; laboratories too?

However, as Hanford came into full and fully satisfactory operation, the only further need for the Project and its staff was to serve in a standby capacity as an emergency scientific "fire fighting" force. This was not merely a matter of administrative decision by the higher "powers that be." Despite countless ideas the scientists longed to pursue, it was the brutal fact that there was no money available that could be spent for any activity not contributing directly to the winning of the war.

The continuing existence of the Metallurgical and Argonne Forest Laboratories in Chicago and of the Clinton Laboratories in Oak Ridge hung in the balance. These R&D organizations that had at long last been brought to a state of full effectiveness in the national scientific and technological interest seemed to stand at the brink of dissolution despite the toil and funds that had gone into their development. The priceless web of interdisciplinary, interpersonal relationships which had been so difficult to establish, which are so imperative to group creativity, and which are so easily dissipated by any form of psychological disarray, appeared to be on the verge of destruction. To many staff members it seemed that an array of unique and vital national assets faced doom, the apparent cause being a case of the hardening of governmental arteries with its attendant bureaucratic inflexibilities that made it impossible for high government to respond to crises outside the bounds of the routines of established "policies and procedures."

The peril to the laboratories was real, the apparent lack of interest in high governmental places was not. Bush and Conant were fully as aware of the need for continuing research and development work in the nuclear field as were the staff. They also were well aware of the continuing need for national, scientific and technological preparedness. And they were doing all that was within their power to resolve the problems involved.

General Groves and Colonel Nichols also were concerned, and they stretched their authority to its limit in order to keep the laboratories going. However, due to the stringent requirements for secrecy, it had been necessary to initiate and to maintain the support of the Project essentially as an activity carried on under the direct authorization of the President as Commander in Chief. This meant that any change in the basic charter under which the Project operated had to be sanctioned either by the President under his war powers, or eventually by Congress once the secrecy bonds were broken.

Clearly, throughout the fall of 1944 and on through 1945 until the bomb was dropped on Hiroshima, only direct Presidential authorization could have sanctioned the changes needed to keep the laboratories operating with their peak effectiveness. Needless to say, at this particular period in history both President Roosevelt and then President Truman were involved in some of the most delicate diplomatic negotiations and some of the weightiest decisions ever to face the nation. That it took time to arrive at a new policy with respect to the Project laboratories is far from surprising. In fact the real surprise is that it was accomplished as soon as it was.

In the meantime the laboratories did suffer serious attrition, but they did survive. And in their eventual restructuring not only were the "mission" needs of the nuclear energy program met but every effort was made to assure that as far as possible the nation would never again be faced with the sort of scientifically and technologically defenceless situation that it did face in January 1942. In the facilities provided and in the interdisciplinary spread of the staff authorized, the laboratories were in a position to initiate action on almost any scientific or technological crisis that might threaten the nation, and to expand swiftly and effectively in whatever direction might be necessary to cope with the crisis.

National Laboratories: today, tomorrow

It is now 25 years later. What of the situation and the role of the laboratories, particularly Argonne, today?

Clearly the nuclear energy mission is a finite endeavor and as such has a definite ending as a major enterprise somewhere down the line. But new scientific and technological missions, some fully recognized and others as yet only suspected, face us on every side. The nation will always need capably staffed and well-equipped laboratories to meet these new challenges. And as our population grows and, in consequence, our society becomes ever more dependent on its science and technology, its requirement for effective preparedness to meet recurring crises in these areas will also grow rather than diminish.

But while the missions change, and the nature of the scientific and technological emergencies with which society must cope are ever new, the core of scientific and technological disciplines required in achieving the necessary solutions does not change. Nor, in general, does the nature of the supporting facilities, of the implementing equipment, or of the basic organizational structure and administrative policies. Specialties and specifics may alter but the fundamentals remain the same.

It is clear to me as I review the inception, the growth, and the present maturity of Argonne that it and its sister National Laboratories are, if anything, even more necessary to the national welfare today than they were 25 years ago, and are enormously more capable of discharging their responsibilities effectively. I see but one change that I would make today in the plans that were drawn up in 1946 and 1947. Today the range of interdisciplinary competence necessary for effective solution of the scientific and technological problems of an affluent and numerically burgeoning society demands the inclusion of the social sciences on an equal footing with the natural sciences, and of the arts of social as well as of technological applications. This one rather considerable expansion in National Laboratory capability seems to me to be imperative.

But, once achieved, I am convinced that the National Laboratories can, and I believe will, continue to play a critically important part in serving the public welfare in times of serenity and in defending its existence in times of scientific and technological storm.

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