The Arthur Williams Wright
Nuclear Structure Laboratory
Yale University

Arthur Williams Wright, for whom the Nuclear Structure Laboratory is named, held the first Ph.D. in science awarded in the New World. His doctoral dissertation – on satellite mechanics – was one of three, in different fields, accepted by Yale University for the degree in 1861.

Dr. Wright was born in 1836 in Lebanon, Connecticut and entered Yale after preparation at Bacon Academy in Colchester and at a private school in Canterbury. He received his B.A. degree in 1859. Both as an undergraduate and graduate student he studied mathematics, mineralogy, botany and modern languages in addition to physics. He also studied law and was admitted to the bar.

From 1863 to 1868 he was a member of the Yale faculty, teaching first Latin and then Physics in the Scientific School. This was followed by postgraduate study at Heidelberg and Berlin and a brief period as Professor of Physics and Chemistry at Williams College before his return to the Yale faculty in 1872 as Professor of Molecular Physics and Chemistry. He held this professorship, later changed to that of Experimental Physics, until his retirement in 1906. Yale's original Sloane Physics Laboratory was built after his plans and under his direction.

Dr. Wright pioneered in many different areas of research in physics and astronomy. He developed the glow discharge preparation of reflecting optics and used these extensively in the first studies of polarization of the solar corona. He first discovered the occurrence of gases in stony meteorites and subjected them to extensive chemical and spectroscopic investigation. Immediately following the discovery of X-radiation, he was the first American to produce and the first to utilize this radiation in his analytic studies.

Dr. Wright was a member of the National Academy of Sciences, and a Fellow of the Royal Astronomical Society. He became Professor Emeritus at Yale in 1906 and died, in New Haven, in 1915.

Dedication, October 5, 1966: Kingman Brewster, Jr., D. Allan Bromley, Glenn T. Seaborg, Denys H. Wilkinson, and Robert J. Van de Graaff

Denys H. Wilkinson
Silliman lecturer

The Professor of Experimental Physics and Head of the Department of Nuclear Physics, Oxford University. Professor Wilkinson is a Fellow of the Royal Society, an Honorary Fellow of Jesus College, Cambridge, and a Student of Christ Church, Oxford. He was associated with Cambridge University from his graduation there until 1957 when he was appointed to his present position at Oxford. While his major interests have been in nuclear physics he has also published work on bird navigation and on church architecture. He is a Founder Member of the Governing Board of the National Institute for Research in Nuclear Science.

Victor F. Weisskopf
Silliman lecturer

Institute Professor, Massachusetts Institute of Technology. A graduate of the University of Göttingen Professor Weisskopf held appointments in Copenhagen, Zurich and at the University of Rochester before joining the Manhattan Project at Los Alamos. Since 1943 he has been associated with the Massachusetts Institute of Technology but from 1960 to 1965 was on leave as Director-General and Scientific Director of the European Organization for Nuclear Research (CERN) in Geneva, Switzerland. During 1960–61 he served as President of the American Physical Society; he is a member of the National Academy of Sciences, of the French Academy of Sciences and of the Federation of American Scientists. He has recently accepted the Chairmanship of the Yale University Council Committee on the Sciences.

D. Allan Bromley
Dedication speaker

Professor of Physics and Director of the Laboratory

Robert J. Van de Graaff
Dedication speaker

Director and Chief Scientist, High Voltage Engineering Corporation. A graduate of the University of Alabama, Dr. Van de Graaff is a Rhodes Scholar and the inventor, while a National Research Fellow at Princeton, of the Van de Graaff Electrostatic Accelerator. From 1934 to 1960 he was associated with the Massachusetts Institute of Technology, resigning his Associate Professorship in 1960 to devote full time to his activities at the High Voltage Engineering Corporation. In 1966 he was awarded the T. W. Bonner Prize of the American Physical Society for outstanding contributions to nuclear physics.

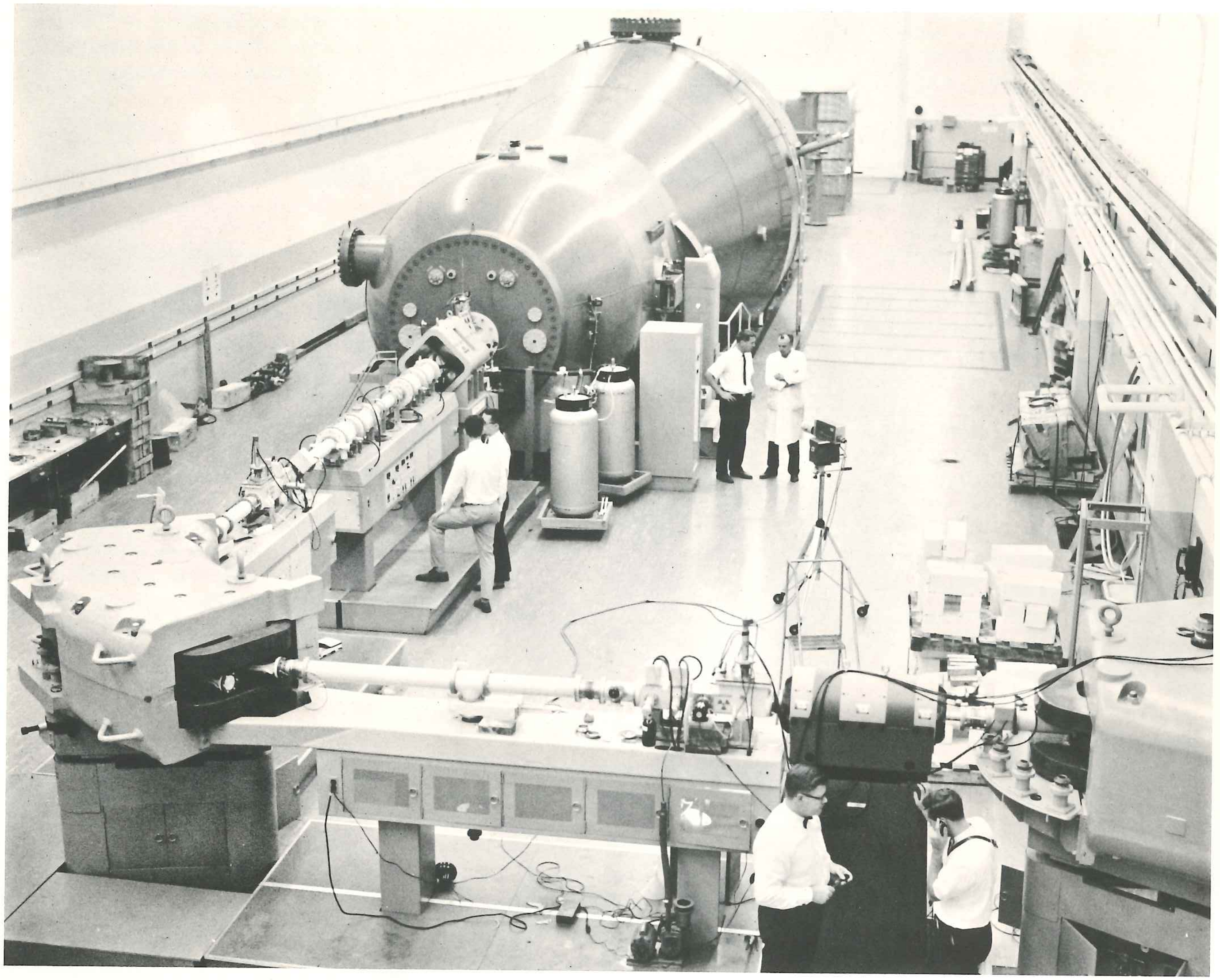
Glenn T. Seaborg
Dedication speaker

Chairman, United States Atomic Energy Commission and Professor of Chemistry, the University of California, Berkeley. A Nobel Laureate in Chemistry, Dr. Seaborg and his associates have been responsible for the discovery of nine of the transuranic elements. He has been associated with the University of California, Berkeley, since his graduation there, serving as Professor of Chemistry since 1945, Associate Director of the Lawrence Radiation Laboratory 1954–1961 and Chancellor 1958–1961. In 1961 he was nominated by President Kennedy to his present post as Chairman of the Atomic Energy Commission. He has received the Enrico Fermi and numerous other Awards, both in this country and abroad, for outstanding work in nuclear chemistry and for leadership in scientific and educational affairs.

Kingman Brewster, Jr.
Dedication speaker

President of Yale University

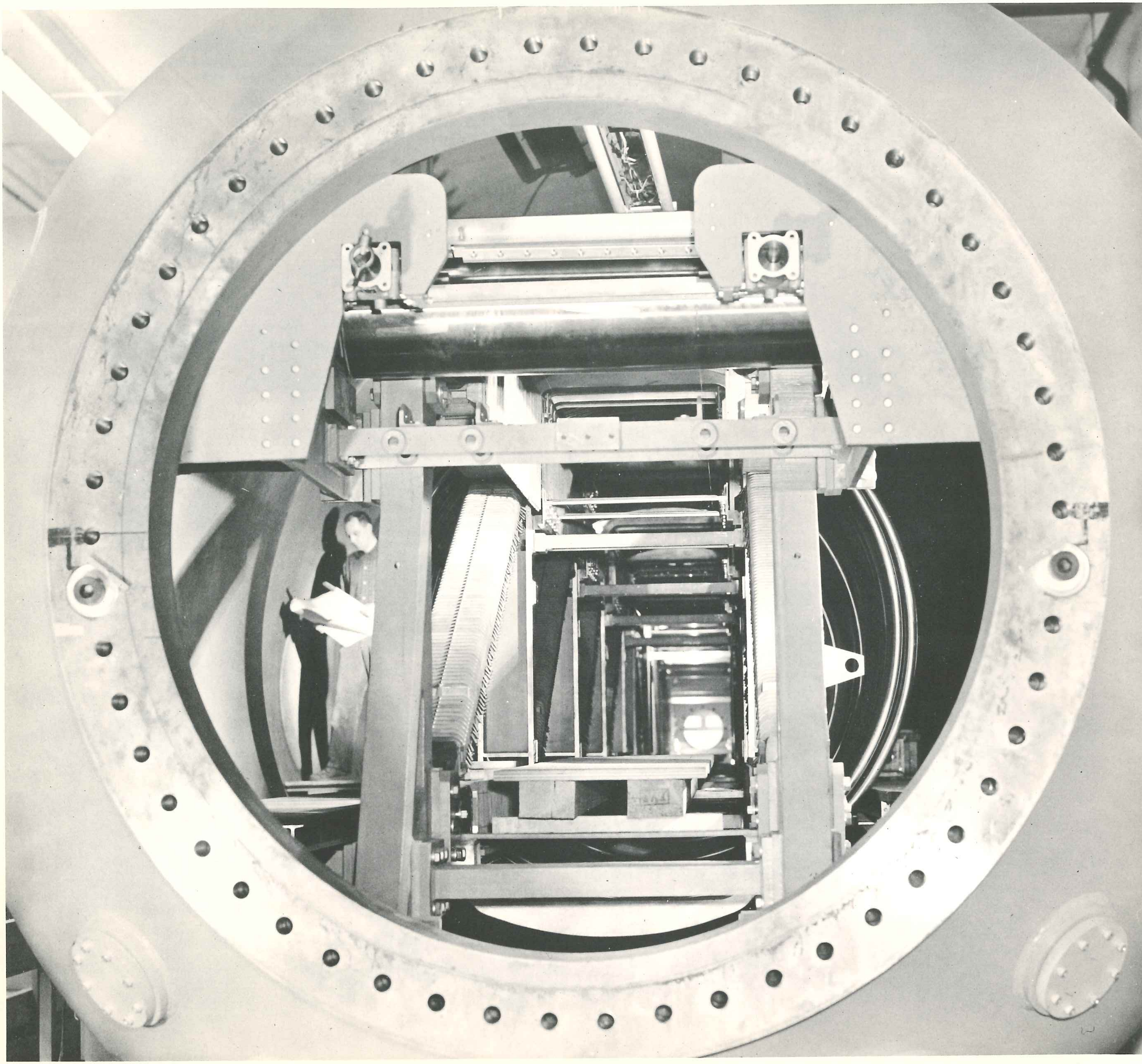
The Emperor Accelerator in the vault of the Arthur Williams Wright Nuclear Structure laboratory. The ion injector appears in the background and the initial beam handling and energy defining elements in the foreground.



Nuclear physics research has played an active role at Yale since the turn of the century. Yale physicists built and operated one of the earliest cyclotrons and the first electron linear accelerator. Some of the earliest studies on both natural and artificial radioactivity, on angular correlation of nuclear radiations, and on neutron time of flight were carried out by Yale workers. In recent years activity has centered on the Heavy Ion Linear Accelerator commissioned in 1958 and on the high intensity Electron Linear Accelerator which in 1961 replaced an older version constructed by the Physics Department staff.

With the commissioning of the world's first Emperor Tandem Van de Graaff Accelerator, the University marks a major expansion of its nuclear research facilities and rounds out an overall capability matched at very few other universities. The Emperor has been designed to accelerate the full range of nuclear species, from protons to the heaviest ions, to energies not hitherto available in beams of high intensity and high resolution. Ancillary equipment includes a variety of scattering chambers, a precision gamma ray goniometer, a large multigap magnetic spectrograph, and a digital computer for on-line data processing; this latter will be used to acquire and analyze data, to control detector systems and, ultimately, to control the operation of the accelerator itself. Such instrumentation will permit effective exploitation of the unparalleled capabilities of the accelerator for precision studies of nuclear structure and behavior. The unique operational flexibility of this facility, together with the other Yale accelerators, opens all aspects of a nuclear structure problem to investigation in a single laboratory. Initial research programs span a broad range of topics in nuclear structure and interactions, ranging from precision mass determinations and tests of charge independence of nuclear forces to study of the neutron-neutron and nucleon-nucleus interactions, of reaction mechanisms, of nuclear molecule formation, and of facets of the fundamental nucleon-nucleon force as revealed in both structure and interaction studies.

Beyond this great potential for fundamental research, the Emperor installation is uniquely suited to its educational function. Using auxiliary research apparatus well within the scope of an individual student, it will permit him to do original work at the frontiers of nuclear understanding. The versatility of the facility also permits the student to approach his nuclear research problem in whatever fashion his curiosity dictates and at the same time involves him in a wide variety of other research fields ranging from solid state through electronics and cryogenics to plasma physics, experience vital to the training of creative scientists.

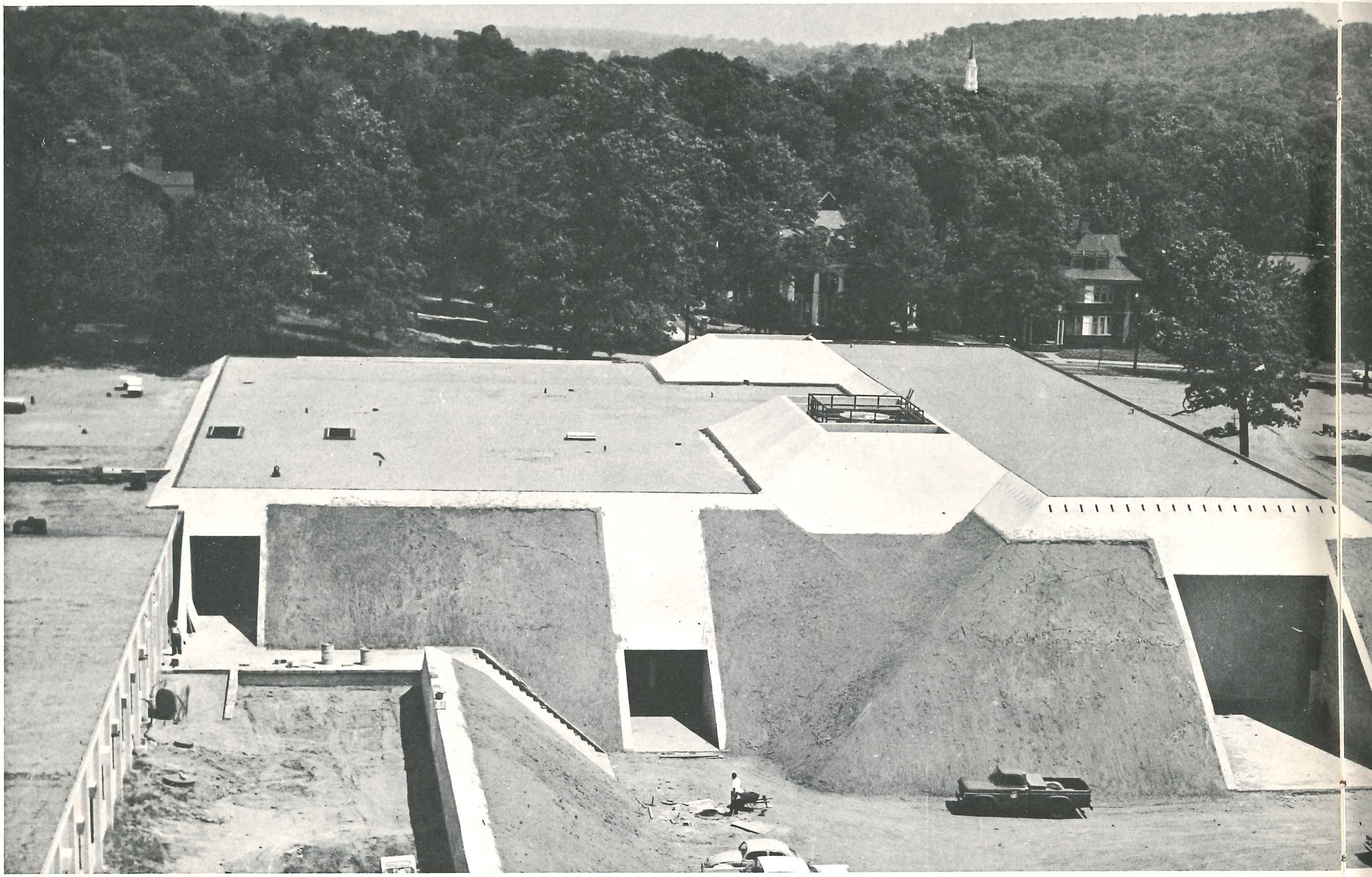


The Yale Model MP Van de Graaff Accelerator Development Chronology

October, 1960	Discussions initiated with High Voltage Engineering Corporation
August, 1961	Proposal submitted to federal agencies
December, 1962	Proposal approved by Atomic Energy Commission
May, 1963	Laboratory construction initiated
November, 1963	Accelerator tank construction initiated
May, 1964	Laboratory construction completed
December, 1964	First voltage on electrostatic structure
December, 1965	First voltage on Accelerator structure
February 18, 1966	First beam through Accelerator
April 6, 1966	First beam on target
May 27, 1966	First experimental data
August 16, 1966	Accelerator accepted by the Atomic Energy Commission
September 26, 1966	First publication (Physical Review Letters)

Opposite page: View of the accelerating structure inside the pressure vessel during installation. The large cylinder in the top of the photograph is the 100 horsepower motor driving the belt which transports charge to the high voltage terminal. Several of the glass and stainless steel beams supporting the high voltage structure are visible in the foreground.

The Laboratory, looking north toward East Rock, during final stages of construction in July 1964. The Heavy Ion and Electron Linear Accelerator Laboratories appear at the extreme left. The three entry doorways lead to storage space, to the offices and laboratories and to the accelerator vault respectively. The truncated pyramids on the roof contain cooling towers for the closed loop water supply in the laboratory. The earth berms are prepared for planting.



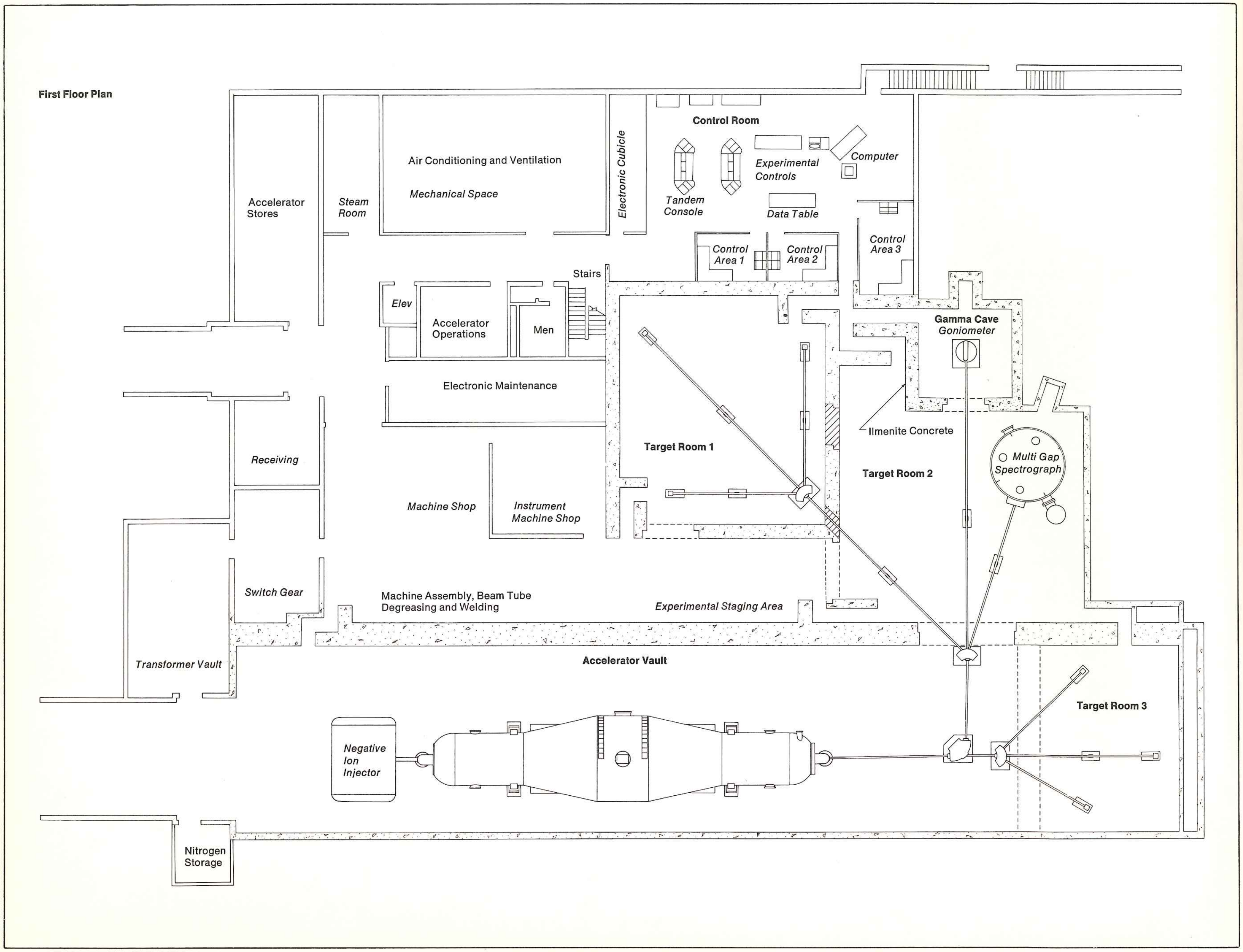
The Arthur Williams Wright Nuclear Structure Laboratory

Funded by	The National Science Foundation ($500,000) Yale Alumni – The Development Fund ($1,425,000)
Architectural design by	Douglas Orr-deCossy-Winder and Associates New Haven, Connecticut
Construction by	George B. H. Macomber Company Boston, Massachusetts

The Model MP Tandem Van de Graaff Accelerator, The Emperor

Designed and constructed by	High Voltage Engineering Corporation Burlington, Massachusetts
Purchased by	The U.S. Atomic Energy Commission Accelerator ($3,100,000) Associated research instrumentation ($2,000,000)

The accelerator vault is 200 by 40 feet in area; a full basement contains many of the mechanical services associated with the accelerator. Only representative beam lines are shown in this plan and a number have not yet been installed. Some 28 experimental locations are planned when all beam lines are activated. The dashed wall sections are now, or in the future will be, composed of movable shielding blocks. The five-foot thick wall between the accelerator vault and the remainder of the laboratory is boron loaded for additional neutron shielding; the vault roof is three feet thick and additional shielding on external walls is provided by the earth berms. The accelerator vault and target rooms are two floors in height but a second floor containing laboratories and administrative offices is above the remaining areas. The overall floor space in the laboratory is 65,000 square feet. The stairs at the right lead to the Electron and Heavy Ion Accelerators.



Distinguished Guests, Ladies and Gentlemen, it is both a pleasure and an honor to welcome you to this dedication of the Arthur Williams Wright Nuclear Structure Laboratory at Yale.

It is particularly fitting that we should honor Arthur Williams Wright in our dedication. In 1861 his dissertation on satellite mechanics was accepted by this University for the first Doctor of Philosophy degree in Science awarded on this continent. As Professor of Experimental Physics at Yale, prior to 1895 and Roentgen's discovery of X-radiation, he carried out research at the forefront of a number of fields, including optics and astronomy. Immediately following Roentgen's discovery Professor Wright was the first in America to produce and utilize X-radiation in his studies. In his primitive X-ray tube, in essence a single-stage electron accelerator, he laid the foundation for radiation physics, and later nuclear physics, in this country and at Yale. We are delighted that members of Professor Wright's family have found it possible to be with us today.

Building on this foundation, nuclear physics has had a long history at this University. Around the turn of the century Boltwood, Bumstead and their collaborators established one of the few internationally recognized centers for what would now be called nuclear research with their discovery of the isotope of thorium, then called ionium, and their related work on the heavy naturally radioactive species. Indicative of the stature of the Yale group at that time is the fact that Lord Rutherford, in leaving McGill in 1907, had tentatively accepted a Professorship here before being seduced away to the University of Manchester and to the discovery of the atomic nucleus.

In later years, Ernest O. Lawrence did work leading to his development of the cyclotron at Yale and although he moved to Berkeley before beginning construction of the first such accelerator the Yale group under Pollard built and operated one of the first few cyclotrons in extensive work on induced radioactivity and nuclear interactions. Immediately following the war Schultz and Beringer initiated construction of one of the first linear electron accelerators, replaced in 1962 by our present high intensity facility; during the 1950's Professor Beringer and his associates, working in collaboration with the Radiation Laboratory group at Berkeley, built one of the first two Heavy Ion Linear Accelerators. For many years Professor Breit and his collaborators have been involved in pioneering work in nuclear theory.

In recent years, based on extensive new information regarding nuclear structure and behavior, we have made major advances in our understanding of nuclear phenomena. This new insight has made it possible to pose ever more sophisticated questions regarding the nucleus and it is essential to continued progress that the precision and delicacy of the probes with which we seek our answers keep pace.

Since its inception, in the earliest days of nuclear physics, the electrostatic accelerator has been characterized by unparalleled precision and flexibility of projectile energy control, and in consequence by the tremendous impact which it has had on nuclear studies. For many decades, however, technological factors limited the maximum available projectile energies so that precise studies could only be carried out on light nuclear species and at low excitation energies in these nuclei.

The energy limitation was first broken in 1957 when our group at the Chalk River Laboratories of Atomic Energy of Canada, Ltd., contracted with the High Voltage Engineering Corporation for the first tandem Van de Graaff electrostatic accelerator. In this, higher projectile energies were attained by using the available D.C. potential to accelerate the projectiles first as negative and then as positive ions utilizing first attraction and then repulsion. This had been first proposed by Bennett in 1936 and independently by Alvarez in 1948. The early name of "Swindletron" reflected this tricking of the projectiles into apparently seeing more potential than was actually present.

It was immediately obvious that this new tandem accelerator represented a significant breakthrough in the instrumentation for nuclear research; this is illustrated by the extensive body of nuclear information which it has made available and by the fact that some thirty copies have subsequently been installed in research laboratories throughout the world. From the beginning it was clear, however, that even these tandems, with a nominal accelerating potential of 5 million volts, were still limited to exploration of the lower half of the periodic table. Several laboratories acquired somewhat expanded versions of this basic machine; these were clearly king-sized and became known as King Tandems. Even these, however, did not permit exploration of the heaviest nuclei.

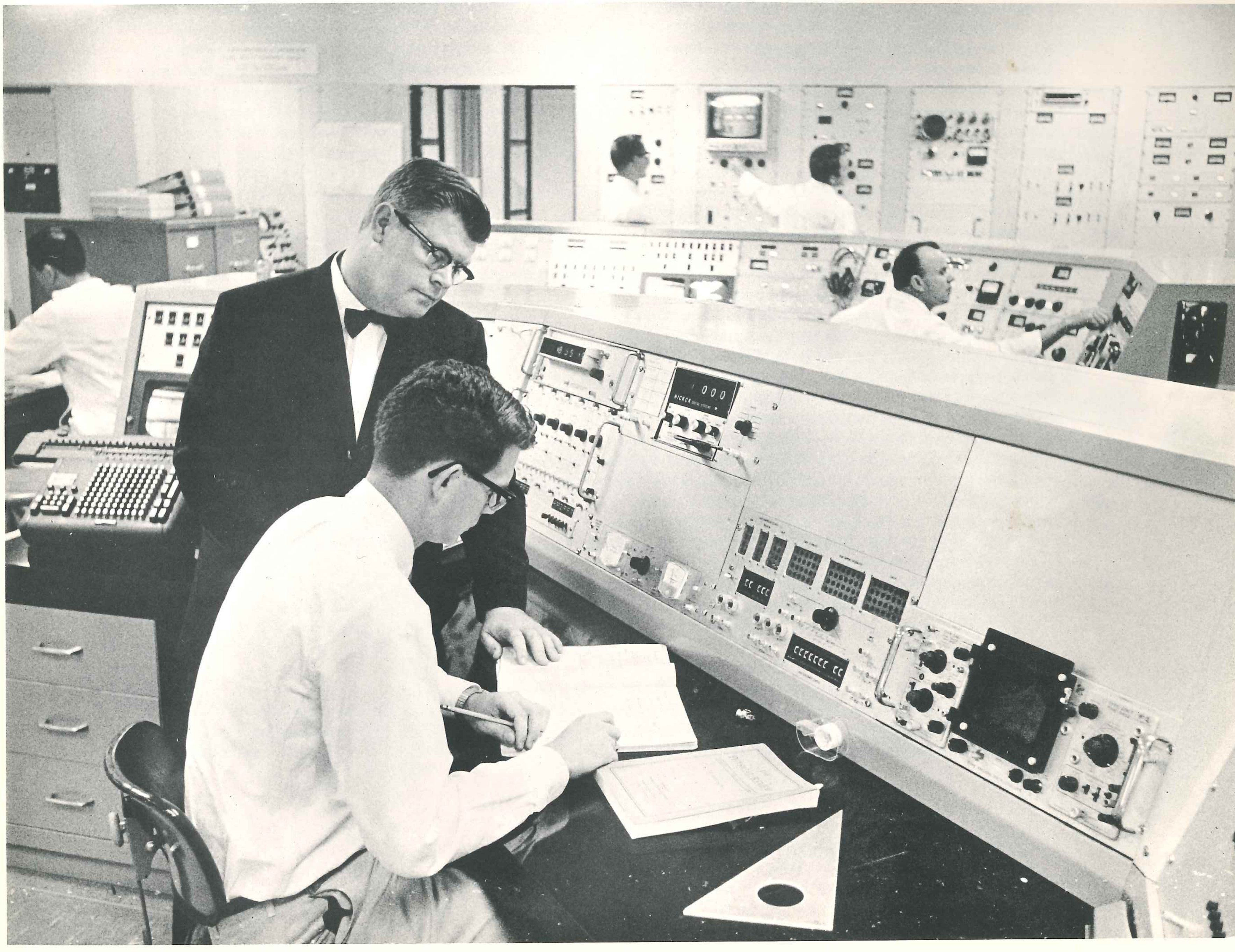
In 1960, in formulating long-range plans for nuclear research at Yale it appeared clear to us that our goal should be the removal of such limitations and the throwing open of all nuclei to precision investigation. We emphasized that this should be coupled with unprecedented beam intensities to permit searching for very improbable, but vitally important, phenomena and with the broadest possible spectrum of beam species to permit not only many avenues of attack on a given problem but also the study of interactions between complex nuclear species themselves, under previously unavailable conditions.

The accelerator which we dedicate today, the Model MP-tandem Van de Graaff, has evolved from these requirements and from long discussions initiated in 1960 with scientific and engineering staff of the High Voltage Engineering Corporation. Since it is much larger than king-sized the name "Emperor" was perhaps inevitable and has been accepted. It is somewhat depressing that High Voltage Engineering has settled on the code designation TU (for transuranium) for the next generation of electrostatic accelerators whenever it is built; HR (for Holy Roman Emperor) would have maintained the tradition.

Approval of our proposal to install the first of these new MP accelerators at Yale was a slightly belated, but deeply appreciated, Christmas gift on December 26, 1962. The accelerator was formally accepted from High Voltage Engineering by the Atomic Energy Commission, on August 16, 1966, having passed all acceptance tests with flying colors, amply justifying our high hopes for it, since the beginning of the project, as a superb instrument for nuclear research. We have accelerated proton beams in the energy range from 1.8 to 23.5 MeV and have obtained beam currents up to 26 microamperes on target, far surpassing the performance of any previous electrostatic accelerator. We have also accelerated heavy ions. Our research program, which insofar as possible has been designed to exploit the unique characteristics of our facility, is now well under way and our first publication from this program has appeared in the September 26 issue of *Physical Review Letters.*

The accelerator is, however, only part of the story. Its

Professor Bromley discusses new experimental results with a student seated at the experimentalists' control console in the accelerator control room. Experimental data from apparatus in all the accelerator target areas appear at this console for evaluation and recording. In the background technicians and graduate students operate the controls for the accelerator itself. All accelerator functions are monitored remotely by special recording circuits and by closed loop television.



effectiveness is, to a tremendous degree, determined by the laboratory and ancillary research facilities which surround it. The cost of this laboratory has been borne three quarters by Yale Alumni, through the University Development Fund, and one quarter by the National Science Foundation through a Facilities Grant. The laboratory thus constitutes impressive evidence of the unstinting support which we have received from the Yale Administration and in particular from President A. Whitney Griswold, in the earliest days, and from Kingman Brewster, Jr., then as Provost, and now as President.

Without the loyal support of our Alumni, and this assistance from the National Science Foundation, it would have been impossible for Yale to take advantage of the Atomic Energy Commission's agreement to install this first Emperor accelerator here. Nor would any of this have been possible without the help and cooperation of many other people and organizations too numerous to name but to all of whom we are deeply grateful. These include our colleagues in the Department of Physics, first under the chairmanship of William Watson and more recently of Vernon Hughes. I would particularly mention my colleagues Charles Bockelman and Jack Overley and the staff of this laboratory for their continuing help, inspiration and support. Drs. George Rogosa and George Kolstad of the Atomic Energy Commission have been of tremendous help as have the scientific and technical staffs of High Voltage Engineering under Dr. Denis Robinson.

The facilities and capabilities of this laboratory complement those of our Electron Linear Accelerator and Heavy Ion Linear Accelerator. When installation of our remaining major research apparatus is completed we, at Yale, will have a unique combination of facilities for the study of nuclear phenomena and for the training of graduate students in nuclear physics. The tremendous potential of these facilities presents us with a solem responsibility to use them in effective and imaginative fashion. This is a responsibility and a challenge which we have long awaited and one which my colleagues and I accept with enthusiasm and with confidence. There is much to be done.

Professor Bromley: *As we begin research work with this new accelerator our sincere congratulations go to the High Voltage Engineering Corporation for the excellence of the instrument which they have produced. We are delighted to have with us today the one man whose vision, initiative and inventive genius are most responsible for this excellence. Son and grandson of Yalemen, he defected to the University of Alabama where his gridiron prowess is legend, and from there went on to Oxford as a Rhodes Scholar. Winner, last year, of the Tom W. Bonner Prize of the American Physical Society for outstanding contributions to nuclear physics, scientist, engineer and inventor of the Van de Graaff accelerator, it is my privilege to introduce to you Dr. Robert J. Van de Graaff, Senior Scientist and Director, High Voltage Engineering Corporation.*

It is a pleasure to be in this laboratory, the latest example of President Brewster's farsighted program for new scientific developments at Yale. About a century ago, Willard Gibbs began his long and outstanding career in mathematical physics at Yale. Today it is good to see that in this new laboratory Professor Bromley and his associates are so ably continuing the pioneering traditions of the past.

For an appreciation of the broad significance and special timeliness of the program of this laboratory for producing and investigating nuclear collisions, it is worthwhile to review briefly the role played by nuclear collisions in the history of the universe. During the last two decades, researches in astronomy and nuclear physics have clearly revealed the basic importance of nuclear collisions in the very creation of the nuclei and atoms which now form the matter around us.

Billions of years ago, a gigantic cosmic event, such as a supernova, is believed to have occurred in our part of the universe. Sufficient heat was created to form a vast plasma of protons and electrons. The nuclear collisions of these protons then formed progressively heavier nuclei so that, by means of such collisions, our present nuclei were synthesized. As the extremely hot plasma cooled down, the various nuclei, being positive, attached to themselves a corresponding number of negative electrons, in this way forming the atoms of our material world. Thus the very atoms that compose our whole material environment were created by means of energetic nuclear collisions. Therefore it is not very surprising that experiments with nuclear collisions have revealed to science a basically new picture of the structure of the atom. This picture is that of the nuclear atom which was discovered by Rutherford in 1911 by using helium nuclei to bombard heavier nuclei. The nuclear atom model supplied the necessary physical foundations for the Bohr theory and for wave mechanics. In 1932, Cockcroft and Walton, by means of a particle accelerator, made their great discovery. In 1938, nuclear fission was discovered. This discovery, which was also made by the investigation of nuclear collisions, was quickly followed by the utilization of nuclear collisions for the liberation of atomic energy, with all its lethal and all its constructive possibilities.

There are encouraging signs that the world is learning to live with the dangerous possibilities of the release of nuclear energy long enough so that it can make use of the gains of this new energy to help relieve the stresses of widespread poverty and a new condition of

**We record here, with deep regret, Dr. Van de Graaff's death on January 16, 1967. This was his last public address.*

stability can emerge in human affairs. Very recently there has been reported an impressive example of constructive nuclear progress. This is the fact that the rate of new orders for large nuclear power plants now exceeds in the United States the rate of new orders for all other power plants combined. The achievement of this milestone in American industrial progress has been made with the leadership of Dr. Seaborg.

Here in this laboratory today, we have an electrostatic accelerator of a new model. This fact probably led Professor Bromley to ask me to say something about the earliest years in the development of this type of accelerator.

My first interest in the possibilities of accelerators came as the result of attending, in 1924, at the Sorbonne the thesis examination of Louis de Broglie. This was the first public exposition of the theory of wave mechanics. As a beginning graduate student, I was attending Mme. Curie's lectures in radioactivity so that when the public announcement of de Broglie's thesis examination listed her as an examiner, I happened to go to the examination. I don't pretend having understood his thesis either then or later but since it dealt with the fundamental nature of particles, it tended subsequently to stimulate my interest in the fundamental need for the acceleration of particles by high voltage.

My first opportunity of discussing at length the possibilities of accelerators came in Holland in 1926 when by chance I happened to share for a week a room at the University of Leyden with Robert Oppenheimer. We were both eager young graduate students and talked far into the night, he about theoretical aspects of proton scattering, and I about possibilities of electrostatic accelerators.

Three years later, I found means of support for laboratory work on electrostatic accelerators. This came through the vision of Dr. Karl Compton, then head of the physics department at Princeton who became president at MIT the following year. He not only made it possible for me to start experimental work in what was then a very unconventional activity, but also supported the work on a larger scale at MIT. After its early beginnings, the progress in this field has been made by many others, and especially under the leadership of Professor Trump and Professor Buechner at MIT. The High Voltage Engineering Corporation founded in 1946 with Dr. Robinson as its president has pioneered in the development and manufacture of electrostatic accelerators for many purposes.

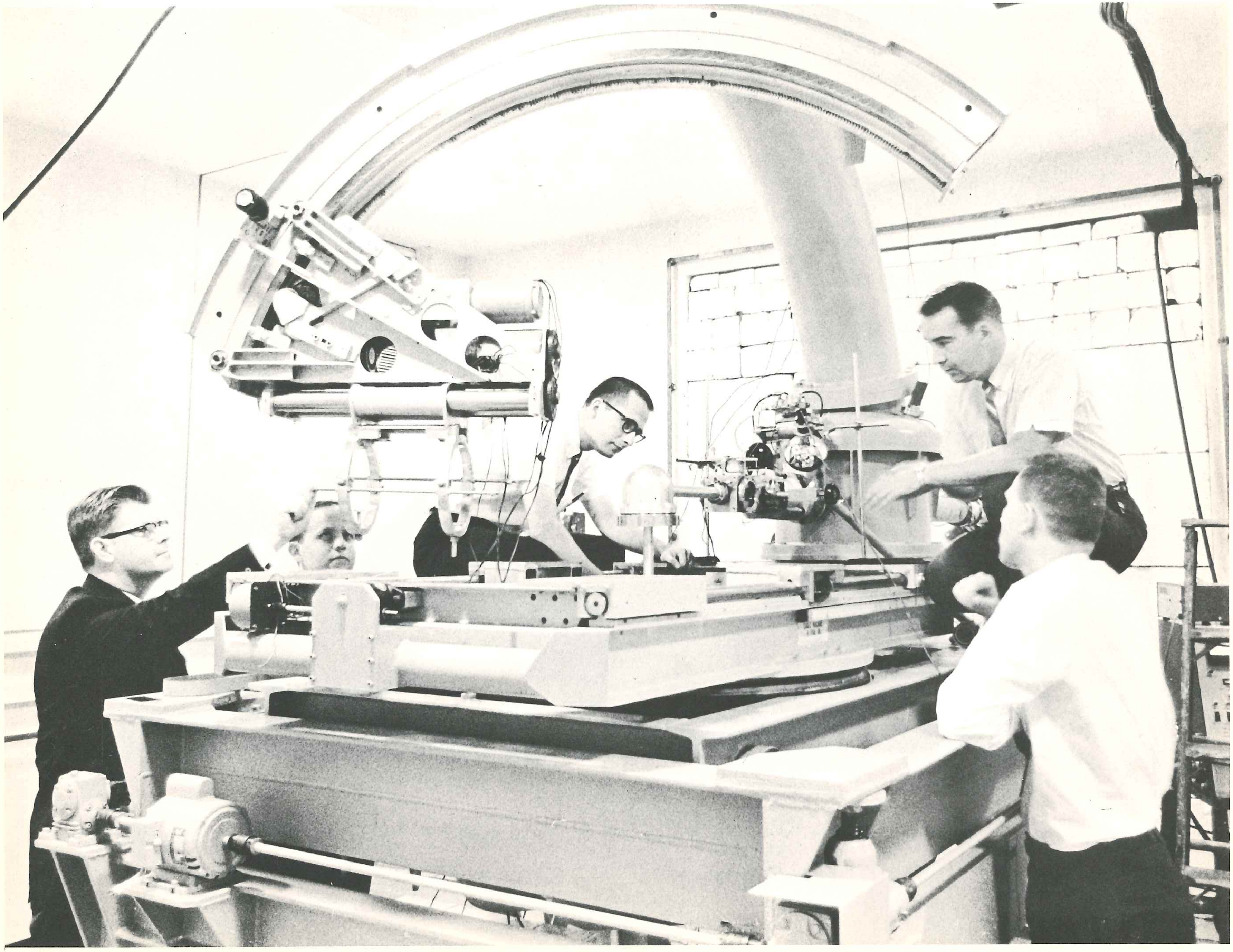
I have already referred to the role of nuclear collisions in the cosmos, in nuclear research, in the power industry, and in military affairs. In all of these various areas, the nuclear collisions have had in common a basic limitation; that is, that the impinging nucleus has been limited to nuclei relatively light in weight. Thus there have been, in these various areas, no appreciable number of collisions between heavy nuclei. This situation has left a great need in the research laboratory for an accelerator capable of making nuclear bombardments not only with nuclei of light and medium weight, but with nuclei of all weights, including the very heavy ones. Professor Bromley has shown outstanding vision and drive in providing here in this laboratory a machine designed to accelerate even the very heavy nuclei. During the last few weeks, tests made at Burlington, using the prototype of the tandem accelerator here, have demonstrated its capability of producing homogeneous beams of bromine, iodine, tantalum and uranium, with some of the particle energies exceeding 200 MeV. These tests have been led by Dr. Rose, with co-workers at High Voltage and from MIT.

With the HILAC already here at Yale, much pioneering work has been done using accelerated ions ranging in weight up to argon. Now this new laboratory can open the way for extending nuclear structure research upward with projectiles of atomic weight ranging from argon on through uranium.

In summing up, it can be pointed out that the cards for our nuclear age were dealt long ago by the original cosmic process. Thus the nuclei in the matter with which we must necessarily work were determined long before mankind arrived on the scene. However, these nuclear cards, so influential in the fate of nations, must now be hurriedly arranged and played. Unhappily, this is occurring at a time of great international stress, and in a situation of vast disparities in national ideology and wealth.

In such a swiftly evolving world, the old saying that knowledge is power becomes a hard fact. Thus it is encouraging that this laboratory is devoted to the advancement of basic nuclear knowledge, and is dedicated here in the thoughtful environment of an old and great university, following in the traditions of Willard Gibbs and Professor Wright.

A group of students carries out alignment procedures on the gamma goniometer installed in the heavily shielded ilmenite concrete cave. This device precisely locates radiation detectors relative to the bombarded target in the centrally located hemispherical target chamber and is entirely controlled by digital devices so that it can be directly connected to the on-line computer.



Professor Bromley: *Distinguished scientist, educator and administrator, our next speaker holds the highest office occupied by a scientist in this country. Nobel laureate in chemistry, he and his associates have discovered and established the characteristics of no fewer than nine of the known transuranic elements as well as over a hundred isotopes of lighter nuclear species. In recognition of his scientific and teaching skills he has received honors and awards too numerous to list from universities and institutions around the world. Professor of Chemistry, Associate Director of the Lawrence Radiation Laboratory, and Chancellor of the University of California at Berkeley, he was nominated to his present post by President Kennedy in 1961. It is indeed an honor to present to you Dr. Glenn T. Seaborg, Chairman of the U.S. Atomic Energy Commission.*

It is indeed a great pleasure for me to return to Yale University today and to participate in the dedication of the Emperor Tandem Van de Graaff Accelerator and the Arthur Williams Wright Nuclear Structure Laboratory. Nine years ago, in May 1957, I had the privilege of visiting this great university to deliver the Silliman Memorial Lectures. I still recall the fine hospitality which was extended to me on that occasion by Professors Wolfgang, Kirkwood, Sturtevant, Nichols and many other members of the Yale University community.

During my 1957 visit I had the opportunity to discuss the research which my colleagues and I had pursued on plutonium and other transuranium elements. I also visited your Heavy Ion Linear Accelerator, which was under construction at that time. Today I am here as a representative of the U.S. Atomic Energy Commission, which, I am pleased to say, has assisted Yale in establishing this new laboratory.

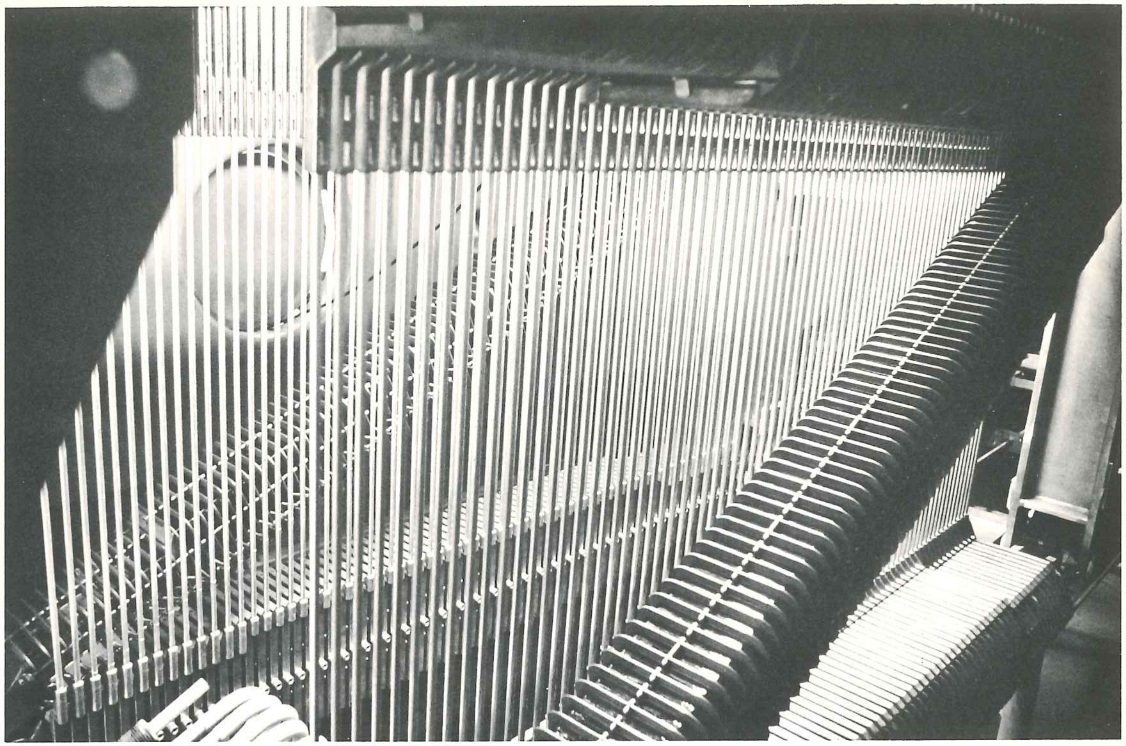
As many of you may know, it was my good fortune to have had the opportunity to pursue research for a number of years at a laboratory in Berkeley, California – a laboratory that was, of course, guided to greatness by the late Professor Ernest O. Lawrence. I am reminded that Professor Lawrence served here at Yale before going west and that he remained a close friend of physics at Yale until his death. His work on accelerator development had a significant impact on nuclear science. And so has the work of Dr. Robert J. Van de Graaff on the electrostatic accelerator which bears his name and which has played an important role in nuclear structure research throughout the world. Dr. Van de Graaff's work has also culminated in this, the first Emperor Tandem – a central subject of today's dedication.

The electrostatic accelerator has come a long way since the first development research by Dr. Van de Graaff at Princeton or even since the days of the MIT Round Hill Laboratory. No longer need the university scientists toil to develop and build such machines. This is now done professionally in the United States on a commercial basis, with detailed consideration toward those machine features which scientists view as important. In fact, I understand that Professor Bromley has had much influence on the design of the accelerator we see here today.

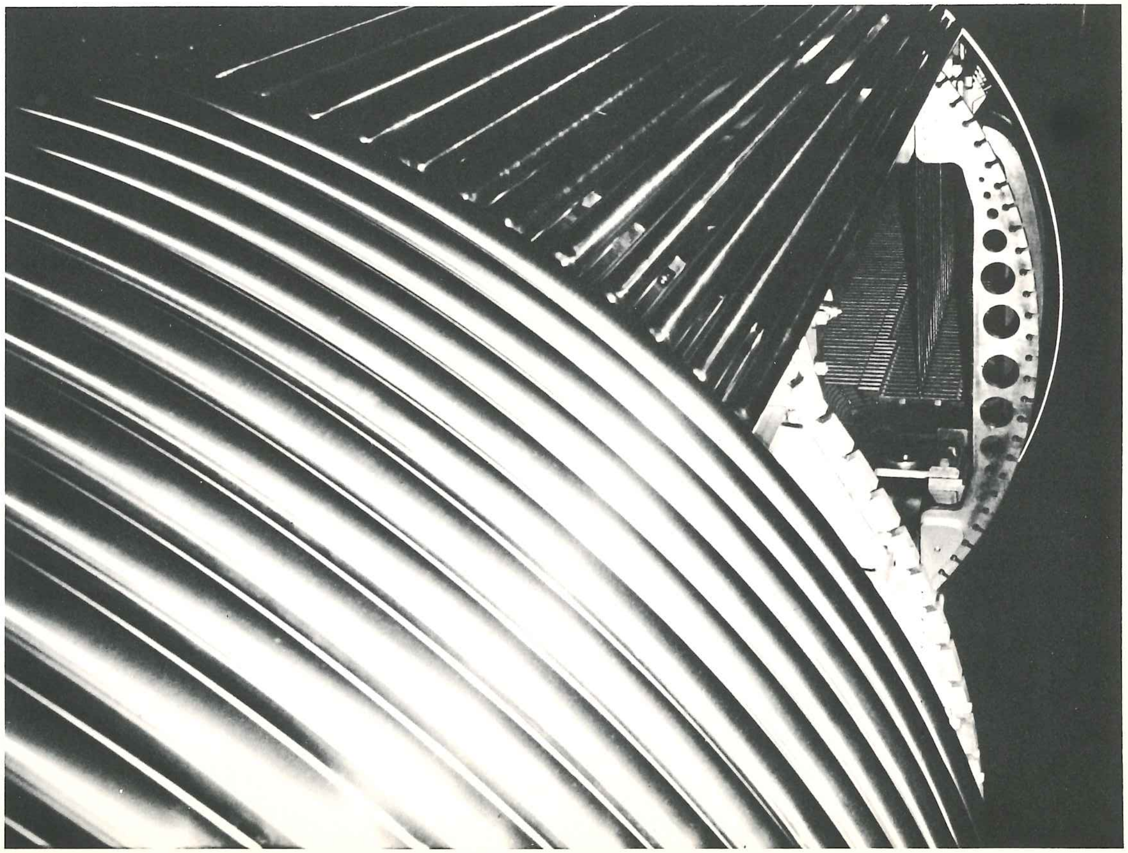
This accelerator makes a major breakthrough in the instrumentation for nuclear research. It is as impressive in its research potential as it is in its physical size – and it is easy to see why this kind of physics has left its once traditional small and dusty basement room.

We no longer need talk of "hoped-for" performance specifications for the Emperor, as we have for the past

Part of the glass and stainless steel bridge structure, inside the pressure vessel, which supports the high voltage terminal. The vertical rods maintain a proper electrostatic environment for the moving belt which transports charge to the high voltage terminal and for the highly evacuated acceleration tube through which the accelerating nuclear projectiles move. This photograph was taken before installation of either the belt or the acceleration tube, and before the electrostatic shielding rings were attached.



The high voltage terminal of the accelerator operating at potentials up to 11.75 million volts. The highly polished stainless steel rings and bars are required to prevent electrostatic breakdown; the rings are six feet in diameter and this terminal is supported by a 40-ton glass and stainless steel bridge in the center of the large accelerator pressure vessel.



several years, for the accelerator has already passed its acceptance tests and these with ease. As we have heard, it has operated at proton energies well in excess of 20 MeV and at beam currents of over 25 microamperes. Such specifications already open up whole new areas to precision study; it is clear that they will be exceeded since this new facility has, very wisely, not yet been pushed near its upper limits of performance. As an accelerator, the Emperor offers beams not only of protons but also of ions of elements throughout the periodic table up to uranium. It couples this with very high stability and energy resolution, with continuous beam character and with readily and precisely variable energy.

As a research facility, this accelerator and this laboratory offer tremendous opportunities. The program envisaged by Dr. Bromley is a diverse but comprehensive one designed to push forward the frontiers of our understanding of the structure and behavior of atomic nuclei and of the forces of the nucleus.

Initial experiments have already been completed and have been submitted for publication. These have not only calibrated the precision energy scale of the accelerator in terms of previously known fixed energies but have provided a whole new set of fixed points in a previously inaccessible region. They have established the masses of a number of little known nuclear species with extreme precision; these are important to an understanding of the role of isobaric spin in the nucleus. It is clear that a vigorous and topical research program has already been established.

This program has been designed to exploit the unique features of the Emperor accelerator. The higher proton energies are being utilized in studies of isobaric analog phenomena, in studies on the detailed structure of the giant dipole and quadrupole resonance in a variety of nuclei and in examination of the fundamental neutron-neutron interactions.

The precise spatial definition of the projectile beams and the broad spectrum of available projectile species fit this facility uniquely to the problems of the structure of complex nuclei. These are vital problems because the nucleus spans the gap between the elementary, few-particle systems, where detailed calculations have been possible, and the many-body systems of solid state and plasma physics where statistical considerations govern. The large gamma goniometer already installed, and the multigap magnetic spectrograph, soon to be installed in this laboratory, have been carefully designed to match the characteristics of the accelerator. They will provide extensive new insight into the behavior of complex nuclei in energy and mass regions previously denied to precision studies.

The goniometer will be the first major piece of instrumentation which Professor Bromley and his associates will place under direct on-line control of a computer-based data acquisition and data handling system now being developed jointly by the Yale group and a commercial computer manufacturer. Symptomatic of the rapid progression in this field, I am informed, is the fact that work is already in progress toward putting even the Emperor itself under on-line computer control. As has always been the case, the interaction of nuclear physics with technology has been a singularly fruitful and mutually beneficial one.

Heavy ion beams have already been used in establishing the operational characteristics of the accelerator and in initial studies on Coulomb excitation of nuclear systems. Here again, the accelerator's characteristics are particularly desirable and a powerful attack is being made on the problems of understanding the vibrations and rotations of deformed nuclei; this includes the characteristics of these deformations and the higher order perturbations in nuclear motion which up until now have simply been ignored but which are essential to a full understanding of nuclear behavior.

Several years ago, when the first tandem accelerator became operational at the Chalk River Laboratories, Professor Bromley and his associates first discovered the nuclear molecule formed from two carbon nuclei. This is essentially an inverse-fission situation and of great interest both intrinsically and for the insight which it may provide into the mechanism of fission. It was not possible to push these studies to heavier nuclear species with the smaller tandems, but I am sure that Dr. Bromley will not be able to resist trying some of these with the heavy ion beams from the Emperor.

These examples indicate the broad spectrum of capabilities of this accelerator and make obvious the reason why duplicate Emperor accelerators are currently under construction at a number of other universities and governmental laboratories, both in this country and abroad.

Of course, we in the AEC are especially interested in the training of future scientists; that is one of the main justifications for locating the accelerator at Yale. What the Emperor can do in this regard is highlighted by the following statement which I have taken from a report by Yale University to the National Science Foundation:

> The new accelerator and its associated facilities will, for the first time, make accessible to precision study all isotopes in nature. These studies, too, will encompass a spectrum of projectile species which will permit unique isolation of the nuclear parameters of interest.
>
> Every attempt has been made in the design of the laboratory to permit exploitation of these characteristics, both in research and in training of graduate scientists. Many problems at the frontiers of nuclear structure physics yet remain within the scope of an individual graduate student. He can conceive, design, and execute his experiment essentially independently. Operational costs of the accelerator do not preclude evolution of his study as his curiosity or interim findings dictate. This we believe to be of crucial importance to the training of creative scientists.
>
> We have designed our building to permit, eventually, some 28 separate sites for experimental apparatus and targets. This, coupled with the inherent beam handling flexibility of the electrostatic accelerator, will make possible very effective utilization of the facility by both students and research faculty.

The Wright Nuclear Structure Laboratory is another important accomplishment under the joint sponsorship of the Federal Government and a university. The Atomic Energy Commission has granted more than four million dollars for the accelerator and other equipment. The National Science Foundation recognized the educational value of this project by providing five hundred thousand dollars through its Facilities Grant Program. Almost one and one-half million dollars were contributed by Yale Alumni through the University Development Fund.

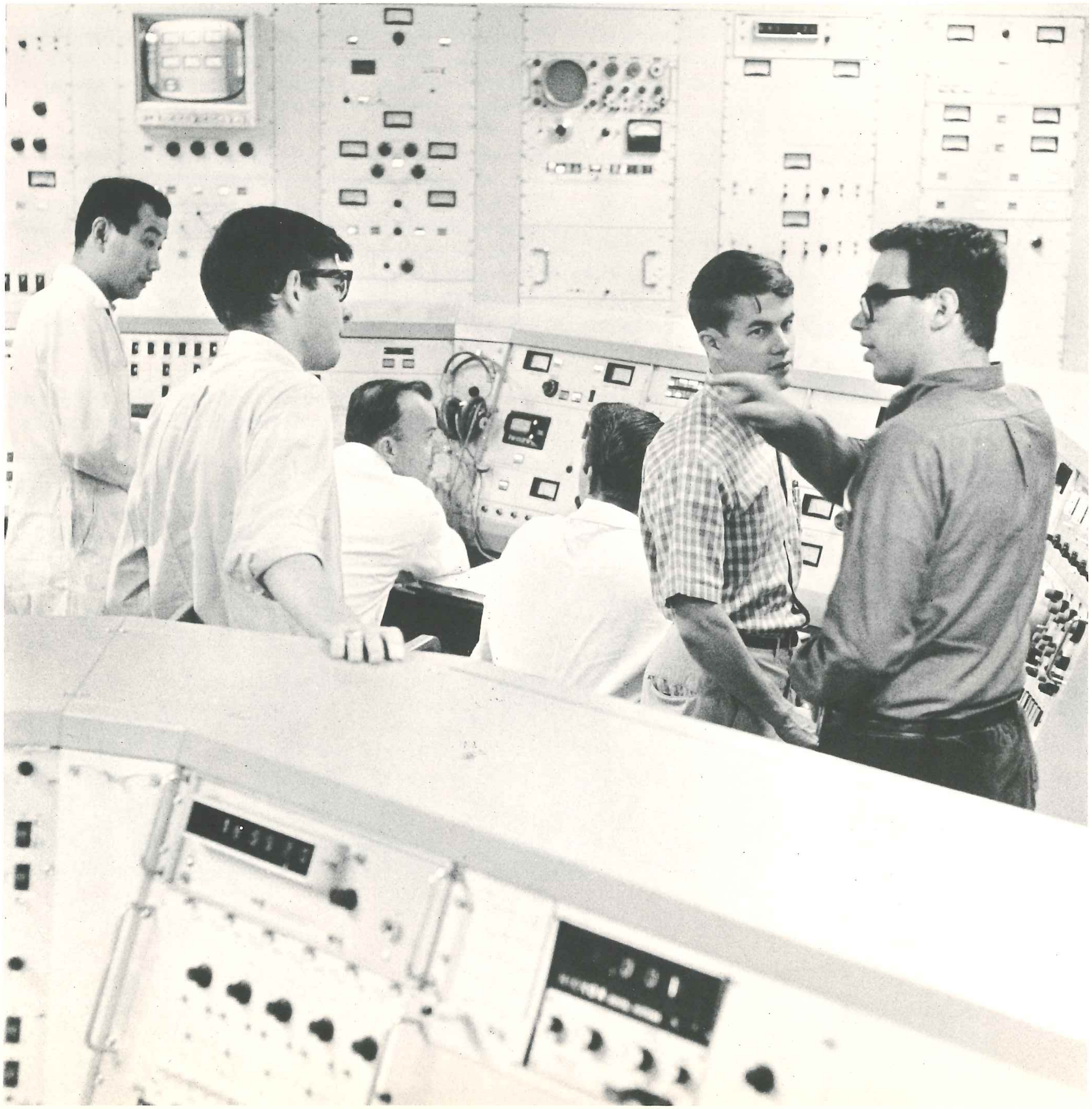
The response of the University and its alumni is especially gratifying, because it was agreed between Yale and the AEC that Yale would build a laboratory facility which would be adequate to house the accelerator provided by the AEC and to carry out the research program. In obtaining maximum advantage from the accelerator, the design of the overall laboratory building is as important as the machine itself. Therefore, this building stands as an achievement which visibly demonstrates the importance which Yale attaches to its nuclear physics research program.

The Emperor Tandem accelerator will offer an educational and research potential of great value both to Yale and to the development of nuclear physics. It will complement the role of the two other Yale machines which are operated under AEC support: the Electron Linear Accelerator and the Heavy Ion Linear Accelerator. The Emperor Tandem will enable the highly capable group under Professor Bromley's leadership to make significant and exciting advances in nuclear physics. Yale can be justly proud of having one of the finest nuclear physics research laboratories in the United States.

In closing, let me congratulate all those who have contributed to developing and building the Wright Nuclear Structure Laboratory and the world's first Emperor Tandem installation. During the years ahead there will be many rewarding experiences for the students and professors who will work and learn here, adding to their own scientific knowledge and skills and to the understanding of nuclear phenomena so vital to mankind in this nuclear age.

On behalf of the Atomic Energy Commission it gives me great pleasure to dedicate this accelerator to such use.

Graduate students and technical staff discuss a problem regarding operation of the accelerator.



Professor Bromley: *Ladies and gentlemen – President Brewster.*

Mr. Chairman, Mr. Seaborg, Mr. Van de Graaff, distinguished guests – both participants and observers – I am somewhat puzzled, because usually on the occasion of the dedication of a new facility, it is the purely formal function of the President to accept the building. That is impossible today because I read in the program that the accelerator has already been accepted by the Atomic Energy Commission.

In a very real sense this anomaly expresses a relationship now quite familiar in American academic science, a relationship which finds the University and the government quite genuinely in partnership. It is a partnership which has been made safe for the University, and I hope worthwhile for the government, thanks to the wise and perceptive statesmanship of a few scientific statesmen, of whom Glenn Seaborg is surely one of the leaders.

The wisdom and experience of the Atomic Energy Commission, in looking upon American universities, not as contractors to produce a work product, but as centers of unbridled initiative worthy of public investment, have been evident in a spirit of willingness to invest in unhampered, undictated, quests of the pure scientists. This has made the partnership possible, acceptable, and, I hope, successful.

I can contribute to this gathering some insight into the way these things happened, how they were accomplished.

As a matter of fact, the history is somewhat deeper in time than our distinguished scientific friends may realize. Two hundred and ten years ago Yale received a machine called an electric-static machine. Unlike the monster before us, this machine could easily be placed on this rostrum. It was a friction machine to create electric static. It was given to the University without charge! It was given – I won't say in return for – but following the conferring of an honorary degree. Lest that seem too cynical, I think you can realize that it came from an incorruptible hand, because it was given to Yale University two hundred and ten years ago by Benjamin Franklin! Unfortunately, that simple expression of gratitude was not indefinitely sufficient for scientific development.

The enormous potential of the talent in our modern Physics Department deserved the support of the most modern facilities possible. Professor Watson and his successor as chairman, Professor Hughes, came to the support of Allan Bromley and Charles Bockelman, who were devising ways in which the most modern facilities for inquiry into nuclear structure could be continued. I remember well – and it seems a long time ago – when Vernon Hughes visited Whitney Griswold and myself on the back lawn of Whit's place at Martha's Vineyard (this showed the perception of a new Physics Department Chairman, realizing that the time to go after the President of a University is when he's on vacation). Although President Griswold had been putting all his energy into the Program for the Arts and Sciences in order to build facilities for departments other than physics, he was perfectly willing to put the University's full faith and credit on the line in order to make it quite clear that fund raising was not the limit of Yale's willingness to allocate resources to science; and, if necessary, Yale would allocate the resources from its own capital and income.

Then, of course, we began our negotiations with the

Atomic Energy Commission. I hoped that my background as a lawyer might permit me to persuade Dr. Seaborg that "machine" meant "machine plus building." But Dr. Seaborg found that interpretation somewhat strained. Then, thanks to the National Science Foundation, we received encouragement with respect to the building as well, and we were able to turn to the Development Fund (contributed in half from the annual giving of Yale alumni and in half from the income of the unrestricted capital given to the Program for the Arts and Sciences) to fulfill Yale's underwriting of the house for this facility.

I don't know why I call it a house. I don't know why I call it a building! If it weren't for the ancient and honorable tradition of various societal organizations in this community, I might refer to it as a "super-tomb!"

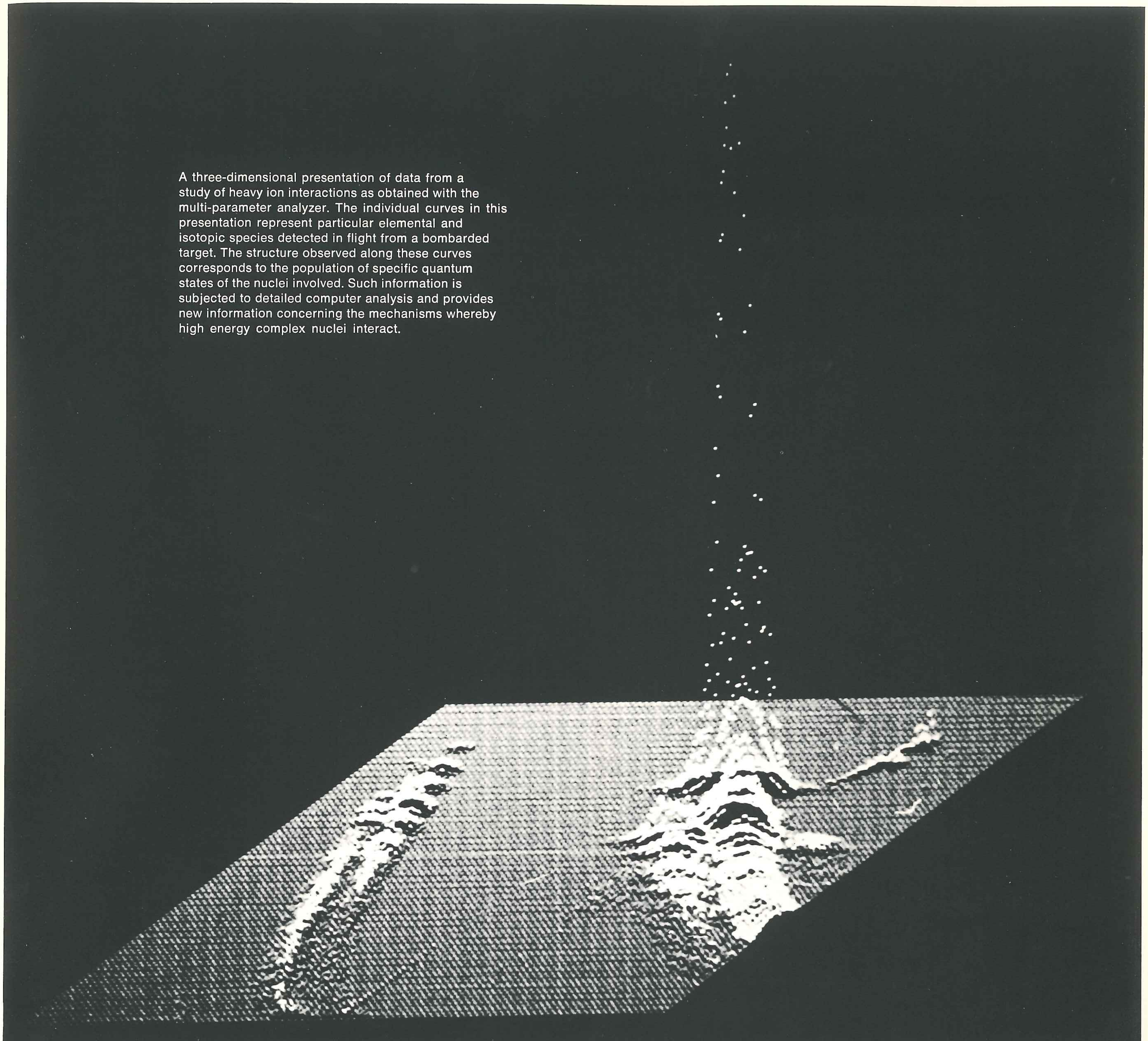
Actually Yale and the New Haven community owe the Douglas Orr firm, and particularly Mr. deCossy, a great debt of gratitude for ingenuity in finding a way of fitting yet another accelerator into the landscape in a way which has added, I think, greatly to the style and elegance of the approach to Yale's science campus from the north.

We now have, here in the Yale neighborhood, facilities for the pursuit of experimental and theoretical physics which I hope are the equal of any – and to use that most dangerous of hucksterish phrases, "second to none." In the constellation of machines for low-energy physics here, in our accessibility to the fantastic resources of the Brookhaven National Laboratory, and in the cooperative neighborhood of our sister institution and its great Physics Department at Columbia, we have indeed created on the East Coast a constellation of facilities, a neighborhood of talent, which I hope, Dr. Seaborg, will even rival that of the Coast which you so recently left.

I think we have done it in a manner which is consistent with the tradition which refuses to admit the bifurcation of research and education, which refuses to see the University as a "service station."

It is with particular gratitude and particular enthusiasm that we accept this accelerator which first gained the enthusiasm of President Griswold, and then that of his successors and his colleagues, because of its educational potential.

It was with that in mind that the President and Fellows chose the name of this laboratory. As we dedicate it, we rededicate ourselves by honoring the name of a man in Yale history. He was the recipient of the first science degree. He went on to contribute to the education of the oncoming generations of scientists at Yale. It is with special pleasure that we rededicate ourselves to the oneness of education and research by honoring Arthur Williams Wright and naming this laboratory for him.



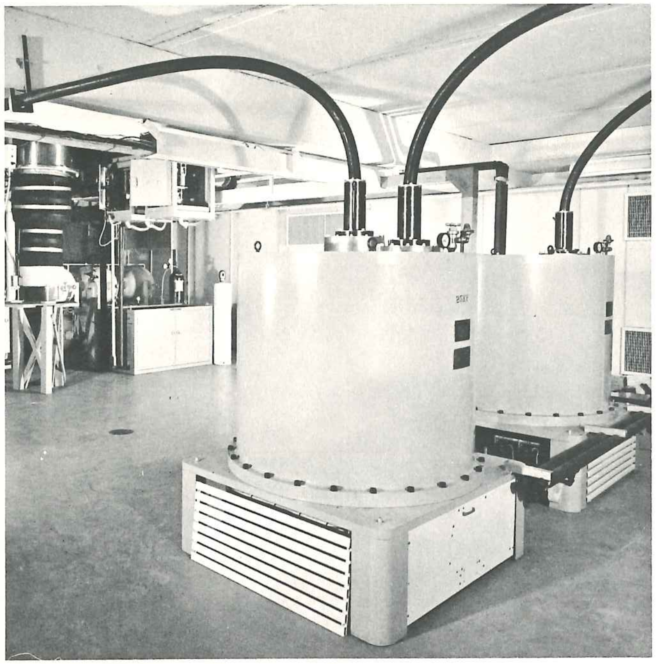
A three-dimensional presentation of data from a study of heavy ion interactions as obtained with the multi-parameter analyzer. The individual curves in this presentation represent particular elemental and isotopic species detected in flight from a bombarded target. The structure observed along these curves corresponds to the population of specific quantum states of the nuclei involved. Such information is subjected to detailed computer analysis and provides new information concerning the mechanisms whereby high energy complex nuclei interact.

A. The 380,000 volt ion source transformers and vacuum pump in the accelerator vault basement.

B. The analyzing and switching magnets which control the beam energy and direct the beam to different target locations.

C. The heat exchanges and chiller of the closed loop cooling water supply in the accelerator vault basement.

D. The negative ion injector which produces the beam projectiles inside its electrostatic shielding enclosure.



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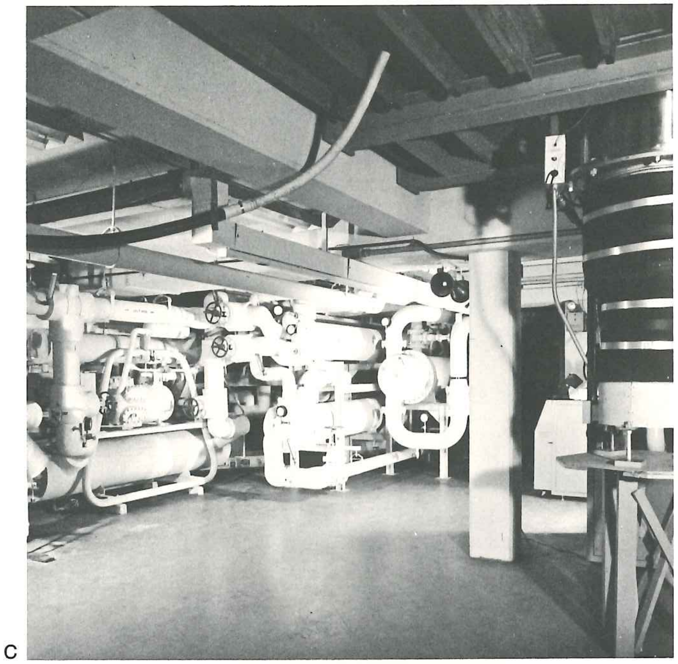


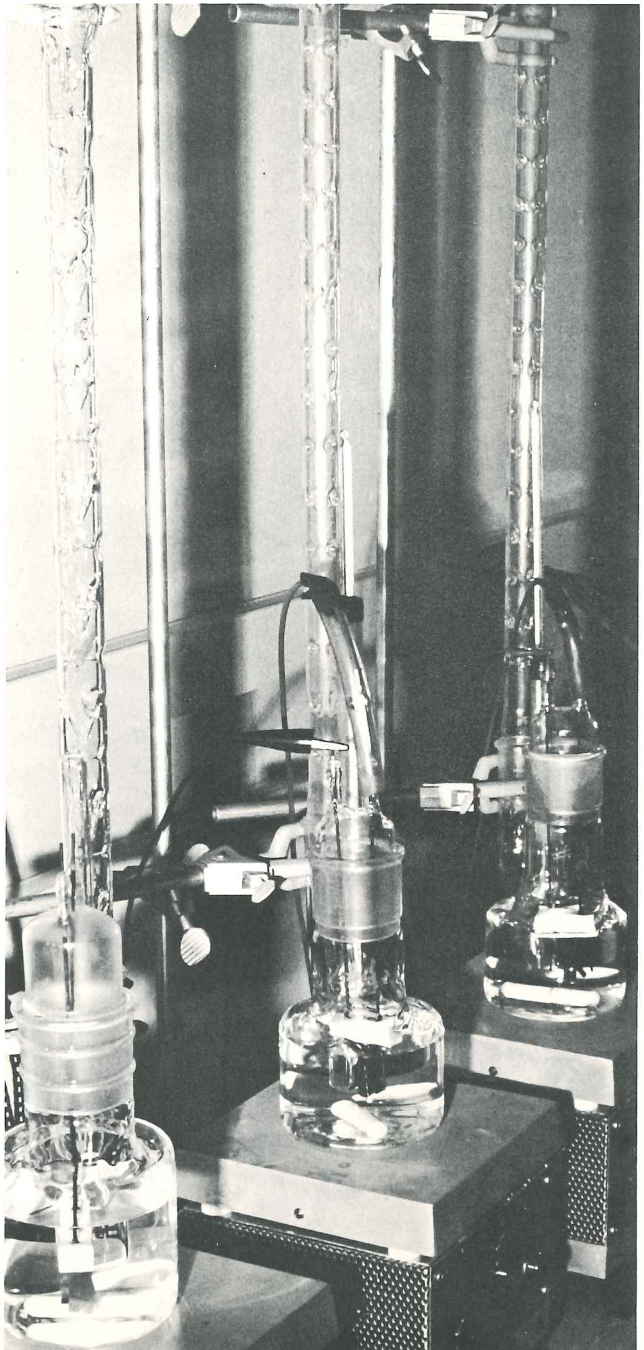
C

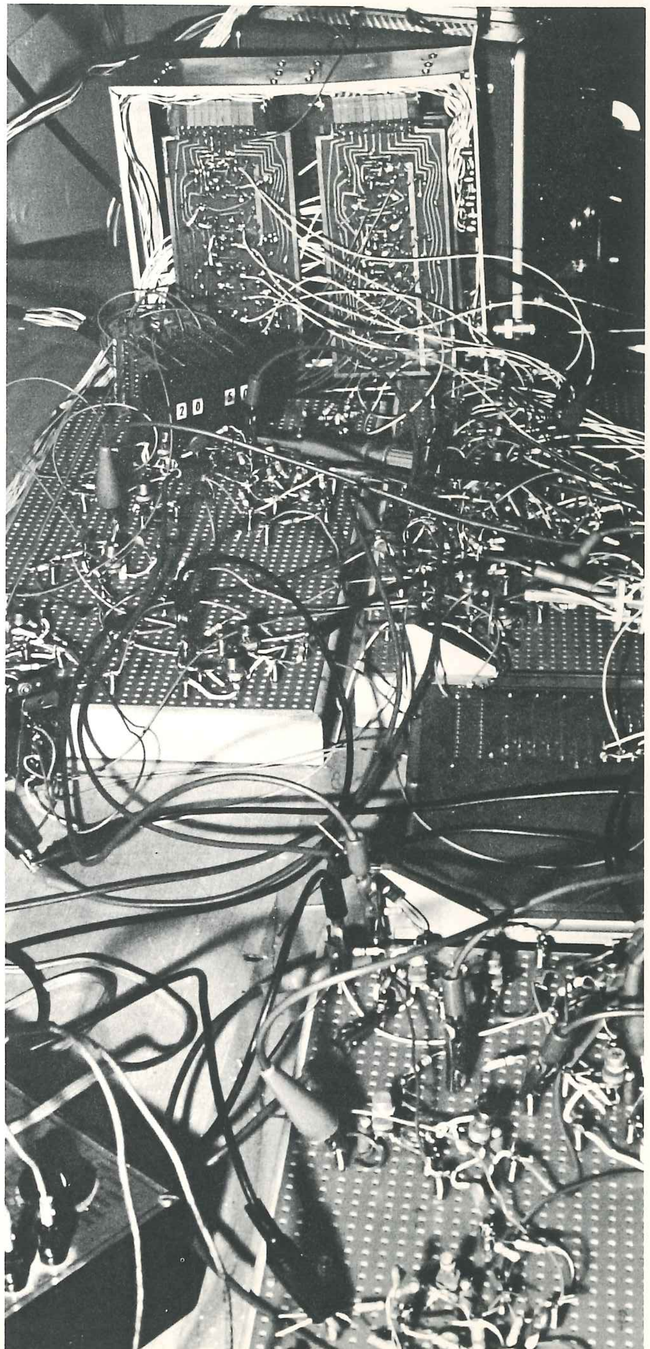
B

D

Drifting ovens in which semiconductor nuclear radiation detectors are prepared by drifting lithium ions through crystals of silicon and germanium. To avoid contamination the drifting process must be carried out entirely in an inert fluorocarbon liquid. These detectors are used in precision measurements on charged particles and gamma radiation from bombarded targets.

A typical "breadboard" study of a new transistorized nuclear instrumentation module. After development in this fashion the circuits are reduced to standard printed card form for inclusion in the laboratory instrumentation system. Standard facilities for the fabrication of printed circuits are available in the laboratory.





The accelerator pressure vessel being moved into the laboratory, March 1964.