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DAVID ALLAN BROMLEY
1926—2005

A Biographical Memoir by

WALTER GREINER AND NEAL LANE

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Biographical Memoir

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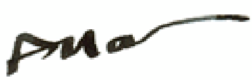

DAVID ALLAN BROMLEY

May 4, 1926–February 10, 2005

BY WALTER GREINER AND NEAL LANE

HAVING GROWN UP as a small boy on a farm in northern Canada without plumbing or electricity, David Allan Bromley went on to become the first Sterling Professor of the Sciences at Yale University, chair of its physics department, and dean of engineering; at various times president of the American Association for the Advancement of Science, the Union of Pure and Applied Physics, and the American Physical Society; the first Cabinet-level assistant to the President of the United States for science and technology; and the Senate-confirmed director of the White House Office of Science and Technology Policy. He was a leading figure in nuclear physics, who made seminal contributions to heavy ion physics by discovering nuclear molecules, studying deuteron stripping reactions and the production of negative ions. Allan was elected to the National Academy of Sciences in 1990. Above all he created a school for experimental nuclear physics at Yale, guiding others worldwide. And in the area of public policy he will be remembered as one of the nation's most effective science advisers to the President of the United States.

THE EARLY YEARS: 1926-1944

Allan was born on a farm near Westmeath, Ontario, Canada. His parents were Milton Escourt Bromley (1893-1979) and Susan Anderson (1906-1963). Ancestors came from central Scotland to Canada in 1854 with a land grant signed by Queen Victoria. The family farm where Allan, his father, and his grandfather were born was established in the mid-1800s and continues to be farmed by Bromleys today. When Allan was growing up, Westmeath had a population of 200. Allan's paternal grandfather, David, lived with Allan and his parents until he passed away in 1932 when Allan was six. Grandfather David was one of the most important influences in Allan's life. He taught Allan to read at a very early age and by four Allan was reading both the Old and the New Testaments of the King James version of the Bible to him. Allan's brothers Robert, Ronald, and John were born in 1932, 1933, and 1935, respectively, while his sister, Dawn, was born in 1940. Allan grew up during the Great Depression. The family farm had neither electricity nor indoor plumbing until he was 17.

(In this memoir we rely heavily on Allan Bromley's personal views given in his unpublished memoirs and transmitted to us by his daughter, Lynn Bromley. Those quotations are enclosed in quotation marks, or called out as extracts in the text. We thank Lynn Bromley for her help.)

ELEMENTARY AND SECONDARY SCHOOL

Allan was seven years old when he entered public school. He walked four miles a day to and from a one-room school house. This unstructured school, which allowed him to progress at his own pace, enabled him to skip grades three and seven completely.

He attended high school in Westmeath. By grade 11 or 12 he already saw his future: "I was reasonably convinced that I was interested in things scientific and technical." He was the only student in his class; so he was given physics and chemistry textbooks and laboratory manuals as well as the key to the equipment cabinet and was told to do as he wished. This sort of unorthodox education method carried with it certain hazards. Allan accidentally blew out the windows on his school building and sprayed acid on his pants. "I still recall that when I got home, my mother cried. It was never quite clear whether she was crying because she recognized what could have happened to me or because we were just coming out of the Depression and it had been a new pair of trousers and they were totally ruined."

Allan didn't attend school in the 1942-1943 academic year as he was the only grade 13 pupil (grade 13 was compulsory before entering university). The university was 20 miles away, which was too far to travel on a daily basis; thus he had to rent a room. Allan worked in a lumber camp for the year to earn enough money to enable him to attend the university. While working in the lumber camp he studied on his own and completed grade 13 by passing the required examination. He graduated as the valedictorian and won a scholarship for general proficiency for the highest score ever recorded in Canada up to the date for the countrywide grade 13 examinations. He also won a scholarship in English offered by Queen's University in Kingston, Ontario, and a four-year scholarship from the Canadian Woman's Christian Temperance Union for his essay detailing the evils of alcohol.

THE "QUEEN'S YEARS": 1944-1949

Since Allan's scholarship resulted from his essay on the evils of alcohol, it was assumed by everyone at Queen's University—including Allan himself—that he was naturally an English major.

With this beginning I managed to spend a year focusing on English but by the end of the year had recognized that were I to continue with this major, I could conceivably starve. Given that Clayton Leach [his roommate and lifelong best friend] was an Electrical Engineer, I had been looking into my options and had discovered that Queen's University had a major in Engineering Physics which effectively combined the electrical engineering training with that in undergraduate physics. As might be imagined, the transfer from an English major to this one was a somewhat brutal one with substantial catch-up required but it turned out to be a life-determining decision.

Allan wanted to serve in the Canadian Air Force, but he was found to be totally color-blind and therefore was disqualified. In 1944 he met his future wife, Patricia Jane Brassor. He worked on his family's farm during his first two summers at Queens University. While in his junior year he worked with Ontario Hydro at a generating station near Niagara Falls.

At the time "after considerable thought I had narrowed the options down to surgery and nuclear physics;" he decided to pursue physics. Allan graduated from Queen's University in May 1948. He won the Governor General of Canada's Medal for the highest-grade score in four years of undergraduate work and also won the Shell Oil Fellowship, tenable for any graduate work. During the summer following graduation, he worked at the National Research Council of Canada in Ottawa, where he was given the task of building an ion source for use with a 600,000 V accelerator.

While at Queens, he worked for a short time with Eric Pickup on his cosmic-ray studies. Indeed, it was this experience that convinced him that he really wished to pursue cosmic-ray physics as a career objective in the years ahead. Allan's research supervisor was Professor J. A. ("Joe") Gray:

I have often thought that had I been asked when I graduated who the worst possible teacher was in the entire university, I would instantly have nominated Joe Gray. A few years later, however, I would have had enough maturity to recognize that he had the greatest impact of anyone on my entire research career.

Allan's first paper was published in *Review of Scientific Instruments* in 1948. It reported work done with R. D. Bradfield on the reconstruction of a Wilson cloud chamber system. His second paper, giving results of his measurements on the neutron spectrum in cosmic rays, was published in 1951 in the *Canadian Journal of Physics.*

He was awarded a scholarship to attend Oxford University, which he declined: "From my experience with Dr. Pickup, I really wanted to do cosmic-ray research." Allan applied for graduate admission to the University of Rochester, Yale University, and the University of Wisconsin. He was immediately turned down by Yale and, while accepted by Wisconsin, he chose to attend the University of Rochester.

He married Patricia Jane Brassor on August 30, 1949.

THE ROCHESTER YEARS: 1949-1955

Allan began his studies at the University of Rochester as a new graduate student in the cosmic-ray section. On his first day the head of the cosmic-ray group died and soon thereafter his deputy was forced to leave the country; so the Rochester cosmic-ray group disappeared, and Allan was told he might want to work on the world's second cyclotron, which was in the school's basement. He was given a budget of $19.72.

The new department chair was Robert Marshak and Allan's new supervisor was Harry Fulbright. Allan was asked to make radioactive ^{18}F. "Apart from the few dollars that I was paid for this activity at the time I thought nothing of it until on September 18, 1980, I was invited…together with two of the original dental researchers from the Strong Memorial Hospital we were awarded gold medals for having originated the inclusion of fluorides in toothpaste."

His dissertation topic was to establish that both ^{14}N and ^{14}C had positive parity. At the University of Rochester, Allan, Harry Fulbright, and Joe Bruner built and used the first variable-energy cyclotron and Allan in particular used it for one of the first deuteron stripping reaction studies outside the United Kingdom to establish that the parity of ^{14}N was in fact even.

After Allan and fellow graduate student Leonard Goldman completed their dissertation research, Fulbright decided that they could convert the old cyclotron into the world's first variable-energy cyclotron by building a high-power variable-frequency oscillator system, a new ion source, a new deflector, and an entirely new beam line.

Allan continued to work with Goldman, Fulbright, and Arthur Gibson (who had sponsored Victor Weisskopf for citizenship when he came from Copenhagen). He was taught physics by Arthur Roberts and others during graduate school at Rochester. Members of his class included Albert Messiah (who became director of the French Saclay Physics Division), Tullio Regge (recognized for his extension of the concept of angular momentum in the Regge trajectories), Albert Petschek (a senior member of the theory group at Los Alamos National Laboratory Physics Division) and Edwardo Caniello. The outstanding faculty at Rochester included at that time Bruce French, David Feldman, Harry Fulbright, Bob Marshak, and Brian O'Brien, the inventor of matrix optics.

After Allan completed the work for his Ph.D., in late 1951, he was invited to join the Rochester faculty as an instructor and taught there for four years. He has said that his best student was Karl Berkelman (who became the director of the Cornell University accelerator complex).

Once they had rebuilt the cyclotron, giving it variable energy, Allan studied the angular distribution of protons and tritons from deuteron-induced reactions on ^{9}Be with Fulbright, Bruner, and Goldman. They published their results in *Physical Review* in 1952.

Based on his dissertation work, Allan published two *Physical Review* papers in 1952 on the determination of the parity of ^{14}N and ^{14}C—the first of these with Goldman. In 1953 Goldman left Rochester and Fulbright, Bruner, and Allan published another *Physical Review* paper on the angular distribution of protons from the $^{19}F(d,p)^{20}F$ reaction.

Allan's son, David, was born on September 28, 1953.

In 1955 Bruner was replaced by Sandy Wall, and the group began to study the elastic scattering of 5.25 MeV protons on nickel and copper. Early in 1956 these measurements were extended to zinc and cobalt targets. Wall and Allan published a *Physical Review* article on their findings and by that time Allan had published his first Chalk River paper with Gove, Litherland, and Almqvist on the gamma-ray branching ratio of the 3.95 MeV level in ^{14}N.

One of the high points of Allan's last year as a graduate student was the Rochester International Conference on high-energy nuclear physics, where he met Enrico Fermi. "Fermi was a truly charming and wonderful person in addition to being one of the world's great physicists."

Allan was promoted to the rank of assistant professor and told that it was a tenure-track appointment. However, when a new president of the university canceled all tenure-track assistant professorships, Allan decided to leave Rochester. He applied to Queen's University for an appointment and was offered an annual salary of $2,800 dollars (Canadian). Atomic Energy of Canada did better for him, and Allan and his family moved to Chalk River in July 1955.

THE CHALK RIVER YEARS: 1955-1960

When Allan arrived at Chalk River, the group utilizing the 4 MV Van de Graaff accelerator consisted of Eric Paul, Harry Gove, Ted Litherland, Einar Almqvist, and John Ferguson. They had access to the world's first liter of ^{3}He gas, which has unique characteristics as a nuclear probe. This made it possible to compete with laboratories worldwide that had higher-energy facilities and allowed for a broad range of nuclear states available for study with the precision characteristic of a Van de Graaff electrostatic accelerator. Work on ^{3}He-induced reactions of ^{12}C was typical of the Chalk River studies in that essentially every aspect of the nuclear structure involved was accessible to the Chalk River accelerator. Allan's judgment:

> The amount of accelerator time available, the quality of the detection and electronic instrumentation available, as well as the complete freedom to select whatever problems for study seemed most interesting, were all unique to the Chalk River Laboratory at the time as was the ability of the group of individuals involved.

Allan's daughter, Lynn, was born on November 7, 1956.

Having demonstrated the special utility of ^{3}He projectiles in the study of the structure of light nuclei, Almqvist, Bromley, and Kuehner undertook to study the reaction mechanism involved in the $^{16}O(^{3}He, ^{4}He)^{15}O$ neutron pickup reaction. A full Breit-Wigner analysis carried out on the data was successful in reproducing quantitatively the interference between the two compound nuclear amplitudes in the experimentally measured cross-section and was something of a tour de force. Having used their ^{3}He beam in extensive spectroscopic measurements on light nuclei they were able to carry out this detailed reaction mechanism study. This was followed by an examination of Coulomb excitation, wherein the excitation of the final nucleus is brought about by the electromagnetic field of the projectile.

In 1957 Allan was selected to represent Chalk River's activities at the Rehovoth Conference in Israel, where he presented four papers. This was the first opportunity that the international nuclear physics community had to recognize the scope and quality of the nuclear physics activities at Chalk River and represented his first trip to Europe and Israel.

In 1955 Chalk River was preparing to acquire the world's first 5 MV tandem electrostatic accelerator. Allan and Almqvist undertook to design a new scattering chamber that would make it possible to measure angular distributions and correlations both in and out of the plane of interaction using previously available bulky detectors. Allan then worked with James Mackenzie to undertake experiments aimed at developing semiconductor nuclear detectors. It was obvious from the beginning that such junction detectors had very important advantages over any that were previously available. He and Mackenzie recognized that the larger band gap of silicon would have real advantages in allowing the operation of equivalent silicon detectors at room temperature. Allan: "Fortunately neither of us knew enough semiconductor physics to fully understand the reasoning for the impossibility of using silicon, but as good experimenters we went ahead and constructed test silicon detectors anyway." They worked perfectly.

He and Mackenzie initiated a patent application and submitted a *Physical Review Letter*, which was immediately rejected as "being of little interest." The patent was finally granted to Chalk River and their lawyers concluded that it had no commercial value. Allan and Mackenzie each received $1 (Canadian) and the patent formally became the property of the queen. Now that silicon detectors have become routine components of the major detectors in elementary particle and nuclear physics and are used in many areas of medicine and commercial technology (e.g., such commonplace devices as home smoke detectors) the annual value of the silicon semiconductors purchased worldwide for such use now substantially exceeds $700 million.

The first so-called EN tandem accelerator was installed at Chalk River in early 1959. This accelerator had a 5 MV terminal but also had the ability to produce 10 MeV protons and 15 MeV alpha particles. Having demonstrated the unique features of the gold-silicon surface barrier and phosphorous-diffused silicon semiconductor detectors with light ions using the 4 MV accelerator, Bromley, Kuehner, and Almqvist utilized the new tandem Van de Graaff to produce beams of ^{12}C ions and scattered them from a thin ^{12}C target.

THE DISCOVERY OF NUCLEAR MOLECULES

Without thinking very much about it, Allan and his colleagues began the heavy ion studies by measuring angular distributions of the ^{12}C ions scattered from ^{12}C targets, expecting they would see, at the relatively low energies at which they began measuring, pure Rutherford scattering, namely, a smooth angular distribution symmetric about 90 degrees in the center of mass. They were surprised to find that this was not the case at all and initially thought that their detectors were faulty.

Obviously something was happening in the ^{12}C plus ^{12}C system that was not apparent in the ^{16}O plus ^{16}O system. In attempting to understand this difference they then measured the excitation functions for a variety of reaction products, including protons, alpha particles, gamma radiation, and neutrons. Clearly at energies around the Coulomb barrier there were resonant phenomena appearing in all these ^{12}C reaction channels; in contrast, the ^{16}O reaction channels showed no such structure.

Working with Erich Vogt and Hugh McManus, their theoretical colleagues, it quickly became clear that what they were seeing was a situation where the ^{12}C nuclei, at energies just below the electrostatic Coulomb barrier, were actually getting stuck in a relatively long-lived moleculelike configuration before fusing into more normal states of ^{24}Mg that subsequently decayed into the observed reaction products.

The name "nuclear molecule" was coined for this phenomenon; and for many years it was tacitly assumed that it was a phenomenon that occurred only with ^{12}C and not with other nuclear species. Subsequent measurement carried out by Allan, Karl Erb, Adriano Gobbi, and their students at Yale using the first of the 10 MeV MP-class tandem accelerators and by a Münster group at low energies succeeded in defining a whole series of resonances in the ^{12}C plus ^{12}C system. Other heavy ion systems also showed these phenomena. They were systematically studied theoretically by the Frankfurt school of Walter Greiner, developing the two-center shell model and showing that the interaction potential between the two heavy ions possesses a potential pocket in which the two nuclei can be captured. The double-resonance mechanism is responsible for the fine structure of the molecular resonances. A molecular channel in the imaginary part of the heavy ion potential, which is energy- and angular-momentum-dependent, regulates the appearance and disappearance of the molecular structures. This is all described in the book *Nuclear Molecules* by Greiner et al. (1995). The book was dedicated to D. Allan Bromley. No doubt, the experimental discovery and theoretical description of nuclear molecules have been key stimuli for the development of the research field of heavy ion physics.

THE MECHANISMS OF DEUTERON STRIPPING REACTIONS

In parallel with the studies on heavy ion interactions using the new 5 MV tandem, Bromley, Almqvist, and Kuehner also undertook a major study of the mechanisms involved in deuteron stripping reactions on a ^{28}Si target. This was in part motivated by Allan's dissertation work at Rochester. Carrying out detailed measurements of angular distributions and angular correlations involving protons and gamma rays associated with low-lying states in the final nucleus ^{29}Si, they were able to extract for the first time the statistical tensors in the deuteron energy range from 6 to 9.7 MeV. These studies were published in 1960 by Bromley, Kuehner, and Almqvist and were widely recognized as being the definitive ones for the understanding of deuteron-stripping reactions. Allan: "The development of precision heavy ion studies in nuclear physics pioneered at the Chalk River Laboratories has influenced the entire field worldwide ever since."

PRODUCTION OF NEGATIVE IONS

In those days all existing atomic physics references suggested that the nitrogen negative ion would have too short a lifetime for acceleration, if it was formed at all. Successful experimenters, however, have learned over the years not to take such statements on faith. So during one evening shift, having completed the planned experiments, Allan undertook to look for the presence of a nitrogen negative ion, which would result in a high-energy nitrogen positive ion exiting from the accelerator. To his amazement he found just that. But when he attempted to reproduce these results the following day, there was no trace of a nitrogen beam. After much discussion (and considerable doubt on the part of others that a nitrogen beam had ever existed) it was discovered that the glass envelope of the radio frequency source had cracked during the prior evening so that a small amount of air had leaked into the source volume in addition to the nitrogen source gas. This cracked bottle had been replaced with an intact one by the accelerator operators early the following morning. Having sorted this out, Allan and his colleagues admitted a little air to the source and immediately reclaimed the nitrogen beam, recognizing that while the negative nitrogen ion did not form or live long enough, the negative molecular ion formed from nitrogen and oxygen did last long enough for its first stage of acceleration. Allan's conclusion: "Serendipity is a vitally important component of experimental research."

Allan felt that Chalk River was extraordinarily fortunate during the period that he was there to have the leadership of Lloyd Elliott as director of the Physics Division and W. B. Lewis as director of the entire laboratory. Unfortunately, they were unsuccessful in obtaining the collaboration of Canadian universities that would have made it possible to bring graduate students to Chalk River. As a result Allan began to feel that he would like to get back to an academic atmosphere where he could interact with graduate and undergraduate students.

THE RETURN TO ACADEMIA

Allan joined the Yale Physics Department, effective February 1, 1960, although he remained on leave from Chalk River until September 1 so that he could participate fully in the planning for the Kingston Conference. This was the 1960 IUPAP-sponsored International Conference on Nuclear Physics with some 400 official delegates from more than 25 countries, including the Soviet Union. The 900-page proceedings of the conference were published by the University of Toronto Press, after having been presented with the entire camera-ready manuscript by Allan and his coeditor E. W. Vogt less than one week after the end of the conference.

THE YALE PHYSICS YEARS: 1960-1989

Of his years at Yale, Allan later wrote,

> Over my career I have been singularly fortunate in having some exceedingly able colleagues with whom it has been a privilege and pleasure to work. There are far too many during the thirty years that I have spent in the Physics Department at Yale for me to list them all, but among the faculty members

I would be remiss if I did not mention are Tom Tombrello, Nelson Stein, Jolie Cizewski, Jack Greenberg, Peter Parker, Karl Erb, Moshe Gai, Robert Ascuitto, and Franco Iachello. It has been a privilege, too, to be associated with an absolutely wonderful group of graduate students. My two original engineers, Charles Gingell and Kenzo Sato and two members of my machine shop Alfred Jeddry and Joseph Cimino deserve special mention also. And last, but certainly not least, I must mention John Baris, our senior computer engineer who often single handedly kept our data acquisition and analysis systems operational and state-of-the-art.

While at Yale, Allan carried out pioneering studies on both the structure and dynamics of atomic nuclei and was considered the father of modern heavy ion science. This was not an easy accomplishment, as Allan faced major challenges every step of the way. Yale had three accelerators when Allan arrived, a heavy ion linear accelerator (HILAC), a linear electron accelerator, and a cyclotron that was obsolete. Allan joined Yale with an interest in developing a new generation of tandem Van de Graaff accelerators. Bill Watson, the Physics Department chair who hired Allan, was enthusiastic about this endeavor. When Allan arrived at Yale, however, he found that Watson had been replaced by Vernon Hughes, who stated categorically that expansion of nuclear physics would never occur at Yale. "This of course, was something of a shock given Watson's earlier promises of support for expansion in my field." Allan's first assignment was to direct the research program at the HILAC. He worked with Bob Beringer, the director of HILAC. "Beringer was without question one of the smartest individuals with whom I have ever had the pleasure of meeting and working."

Allan's first student, Ken Nagatani, was sent to him by Professor Haru Morinaga at the University of Tokyo.

For the first six months of our interaction I was unable to understand a word that Nagatani uttered and he much later pointed out that he could not understand anything that I had told him during this same period. We did learn however that if we had managed to communicate Ken would bow from the waist, whereas if there had been no information transfer he would simply nod his head, and on that basis we began experiments with the HILAC.

With Ken Nagatoni, Allan published work on α-particle-induced breakup of the deuteron. Nagatoni became a friend and colleague for years to come.

His second student was Albert Howard who had been working on gaseous isotope separation in thermal diffusion columns. Allan felt it was important to keep his hand in nuclear structure studies for which the HILAC was totally unsuited, so he arranged to have access to the 3 MeV Van de Graaff accelerator at Brookhaven, and he and Howard spent several months in the summer of 1961 working at this facility.

The next group of students sought out Allan as a possible supervisor for their Ph.D. dissertations. They included Martin Sachs, Joseph Allen, James Poth, and Joel Birnbaum. These and other early students were always very special to Allan. He enjoyed working with them at Yale, kept in close touch with them, and was enormously proud of them:

It has been a great privilege working with all of my Yale Physics Ph.D. graduates through the years. They now comprise what is in essence an extended family from whom I hear about events in their lives both large and small. This is most certainly one of the greatest attractions of an academic career.

Allan quickly determined that the Yale HILAC was totally unsuited for nuclear physics, specifically for nuclear structure physics, because of inadequate beam energy resolution and directional beam stability.

However, Allan had not given up doing nuclear spectroscopic studies as he and one of his graduate students Gregory Seaman constructed a large cave of blocks of ilmenite-based concrete lined with paraffin to slow down neutrons and borax to capture these slow neutrons, then a 6 inch layer of lead bricks and finally a graded shield of various metals. All of this was finished with a lining of copper.

Although the cave was a great success and is still used for low background experiments, the vagaries of the HILAC beam made it impossible to do any of the experiments of interest to Allan. Allan: "By November of 1960 it had become very clear to me that if Yale was to remain competitive in nuclear physics, as I knew it, it was going to be necessary for us to develop a completely new, high-precision facility." Despite the objection of the chair of the Physics Department that is exactly what Allan did.

Allan first thought of a single-ended Van de Graaff accelerator with a 10 MV terminal. High Voltage Engineering Company (HVEC) determined that this was not possible but a tandem with a 10 MV terminal was a possibility. Since a 7.5 MV terminal existed and was called a King, Allan decided that the only suitable title for a 10 MV terminal was MP, or Emperor tandem.

Allan's desire to build such an accelerator was in direct competition with the Physics Department chair, who was involved in what turned out to be the Los Alamos Meson Physics Facility (LAMPF), which was a very much bigger operation than the tandem. Yale could not fund both of these and much debate and animosity resulted. Allan:

> The combination of this relationship with my department chairman and the quality of the facilities that I had available on campus with which to do research, over a relatively short time convinced me [that] in leaving Chalk River, which was then clearly one of the best equipped laboratories in the entire world, I had made one of the largest mistakes in this entire scientific community. Happily, as things evolved, I changed this opinion and in subsequent years have had a wonderful time at Yale and with a Yale base.

Allan finally won the support of the Yale board to continue with his 10 MV tandem program and then had to pull together a group to work on the detailed design of both the accelerator and the laboratory that would house it. Charles Bockelman was Allan's senior colleague from the Yale faculty along with Tom Tombrello from Rice University.

Designing target rooms to accommodate a large number of graduate students and shielding the laboratory adequately were two major issues. Kenzo Sato joined Allan in 1962 with major responsibility for the installation of the tandem and its various subsequent upgrades. Karl Ecklund also joined as the formal assistant director of the laboratory and took on a large share of the administrative duties.

In July 1961 Allan submitted his original proposal for the new accelerator to the Atomic Energy Commission (AEC) and the National Science Foundation (NSF). Late in 1962 the AEC informed Allan that he would have the first ever MP and that AEC would provide the entire $5 million necessary for the accelerator and associated instrumentation. The AEC, however, refused to provide the additional $2 million needed to build the laboratory to house the accelerator. After much effort by Allan and with the strong support of the president of Yale, Kingman Brewster, the Yale board of directors agreed to use $1.5 million of university funds toward this construction, which enticed the NSF to provide the additional $500,000. Construction began in May 1963 and Allan and his colleagues took occupancy of the building on May 4, 1964, Allan's 38th birthday. They reached voltages on the MP terminal in excess of 10 MV first on November 25, 1964, and very shortly thereafter began the experimental program.

NUCLEAR THEORY AND THE APPLIED NUCLEAR PHYSICS PROGRAM

Allan had always thought that graduate students tend to learn much more from interactions with other graduate students than they do from thesis supervisors, courses, or other faculty members. This in part was also why, from the very onset of the laboratory's activities, he attempted to maximize the daily contact between theorists and experimentalists. He invited a number of theoreticians from abroad (e.g., Walter Greiner, Berndt Müller) and considered it a major coup when in 1978 Yale was able to attract Professor Franco Iachello, one of the world's most distinguished nuclear theorists from Groningen, in the Netherlands, to head nuclear theory activities at Yale. Karl Erb joined the lab in 1972 and Bill Langford joined in 1973.

Allan also felt that students would learn more by being involved in applied physics work as well as fundamental nuclear studies. Thus, Allan and his colleagues acquired a 300 kV accelerator for the purpose of carrying out studies in applied nuclear physics. Among their findings was a method of measuring the age of glass.

Perhaps the most important of the discoveries in applied nuclear physics related to the treatment of metallic—usually titanium or special stainless steels—prostheses prior to their installation surgically into the body. The Yale group found that if these prostheses were bombarded with 1 MeV nitrogen ions, a subsurface nitride layer would form and the corrosion rate would decrease by factors between 700 and 1000. They were also able to acquire a 4 MV single-ended Van de Graaff accelerator in the mid-1970s. This allowed them to cover the intermediate range between the 300 kV and tandem accelerators.

The MP tandem laboratory at Yale was officially dedicated on October 5, 1966, an event attended by senior members of the nuclear community from around the world, including Robert J. Van de Graaff. The laboratory was named after Arthur William Wright, who had the distinction in 1861 of having received one of the first three Ph.D. degrees awarded outside Europe. His Yale Ph.D. thesis was entitled "On the Removal of Matter from an Object Entering the Earth's Atmosphere at High Velocity." As Allan said, "He was well ahead of his time!"

Allan and his colleagues at the laboratory found that the Yale University computing facilities were not adequate for their needs. Thus he set up a joint program involving IBM, the AEC, and Yale to develop a truly state-of-the-art data acquisition and analysis system.

LECTURING IN NUCLEAR PHYSICS

When Allan first joined the Yale faculty, one of his reasons for returning to academia was to write a textbook on nuclear physics. With that in mind he agreed to teach the graduate course in nuclear physics. Allan:

> This, however, was a period of very rapid growth in the understanding of both nuclear structure and dynamics and, having taught this course for two years, I was forced to conclude that much of what I had taught in the first year, by the second year was not only obsolete, but wrong! After a third year of teaching the course, I dropped the idea of writing a textbook since I was convinced that it would be obsolete before it was published.

Nevertheless many years later he did edit an eight-volume series on heavy ion science (1984, 1985, 1988).

In 1964 Mary Anne Thomson, now Mary Anne Schulz, joined the laboratory as Allan's executive assistant. "She has made massive contributions to my work, to the work of the Laboratory, and to the careers of all of the students who have passed through it, quite apart from being a close and loyal friend whose advice I have sought on an enormous range of topics."

THE COMMITTEE ON NUCLEAR SCIENCE AND THE PHYSICS SURVEY COMMITTEE

Allan was asked in 1964 by Professor Robley Evans of MIT to replace him as chair of the National Research Council's Committee on Nuclear Science. The work on this committee gave him a window into the operations of the U.S. government, both its legislative and executive aspects, and in addition, provided a channel through which he came to know personally a large fraction of the leadership of the American nuclear science community. In the late 1960s the National Academy of Sciences felt that it was time for a new overview of physics. Allan was asked to chair the Academy's Physics Survey Committee.

Apart from the survey committee itself, subpanels were convened in each of the major subfields of physics; and for the first time, crosscutting panels were also assembled to focus on education in physics, publication in physics, interaction of physics with biology, and information in physics. The final report was published by the National Academy Press (NAP) in June 1972. In addition to the main volume, the NAP published three volumes containing the reports of the subpanels, another volume intended particularly for physics students, as well as a fifth volume with the committee's recommendations addressed to the federal government. It was recognized as a model for presentation of the needs and aspirations of a field of science to government as well as to the entire community in that field. During this period, at the request of the AEC, Allan chaired a committee examining the management of the Argonne National Laboratory.

Allan continued to serve the Academy in several capacities, as a member of the Executive Committee of the Assembly of Mathematical and Physical Sciences (1967-1978) and as chair of the Office of Physical Sciences (1975-1978).

EARLY INVOLVEMENT IN POLICY: NIXON ADMINISTRATION

As a result of Allan's leadership in the physics and academic community, he was invited to serve (1973-1989) as confidential consultant to the Nixon Administration as a member of the Science Policy Working Group, one of several working groups arising from the 1972 Nixon-Brezhnev meeting. Allan also was a member of the U.S. delegation to the International Council of Scientific Unions (1976-1987), including a term on its Executive Board (1982-1983).

Allan had become aware that there was no American presence in the International Union of Pure and Applied Physics (IUPAP). Thus, Allan was happy to serve on the U.S. National Committee for IUPAP (1965-1975) and was then elected vice president, and in 1984, president of the IUPAP, serving from 1984 through 1987. For him, one of the most memorable activities as president was getting both the People's Republic of China and Taiwan separately admitted as members of IUPAP.

Allan's path to U.S. citizenship was unusual. During an AEC directors meeting in Las Vegas in 1970, Allan was shown how to trigger the hydrogen bomb. Since he was not an American citizen this was a problem. Allan: "They had two choices. Either shoot and bury me and pretend that I had never been there or make me a citizen as rapidly as possible. Happily they chose the latter, but only after some discussion!" Allan and his wife, Pat, formally became U.S. citizens on March 29, 1970.

In 1975 a generous benefactress from New Haven offered Allan $250,000 per year for research that was pertinent to the energy crisis that had just unfolded. Allan accepted and used the donation to support graduate students under the title of Wright Fellows, as she wished to remain anonymous. She continued this generous contribution each year until Allan joined the George H. W. Bush Administration in Washington in 1989. Allan met her many times and was indebted to her as "she had a profound effect on the lives of a great many young scientists." Between 1965 and 1989 Allan's laboratory alone graduated more doctoral students in experimental nuclear physics than any other institution in the world.

Although Allan was offered many prestigious positions elsewhere during the 1970s and 1980s, he decided to stay at Yale. In addition to his love for the university, he felt a special responsibility to stay at Yale because in 1970 he had been appointed to chair the Yale Physics Department (and served until 1977). Allan felt that the department should include a major activity in astrophysics and was "extraordinarily fortunate" in getting James Bardeen for this. Bardeen left in 1977. Prior to Allan's leadership, the department had also lost the condensed matter physics program. In Allan's opinion this was a mistake because in the national rankings, the department usually found itself ranked number 10 or tied for that ranking; whereas if the department had retained condensed matter, Allan was completely convinced that the department would rank either 5 or 6. In 1972 Allan was appointed the Henry Ford II Professor by Yale President Kingman Brewster.

INITIAL UPGRADING OF THE MP ACCELERATOR

A decade after he began research with the MP tandem in the A. W. Wright Nuclear Structure Laboratory, Allan and his colleagues upgraded the accelerator performance through the installation of new acceleration tubes. With this improvement the accelerator operated up to 13 MV on the terminal. But other developments in the field were pushing for higher energies. Heavy ion physics obtained tremendous momentum due to the theoretical prediction of superheavy elements, atomic quasi molecules with high central charge, and resulting from that the possibility to extend atomic physics into new domains and fundamental processes in quantum electrodynamics of strong fields (vacuum decay). In many discussions and seminars one of the authors (W.G.) outlined these ideas at the Wright laboratory; Jack Greenberg and Allan were fascinated. Certainly, hearing about these physics opportunities provided one of the motivations for Allan and his colleagues to increase the terminal voltage of their accelerator to 20 MV. This new accelerator was labeled STU (stretched trans-uranium) reflecting the greater length of the proposed tanks and the fact that it would be able to accelerate all ions up to and including uranium.

The funding proposal submitted to the Department of Energy was denied for two years, but after much effort by Allan and with the active involvement of Yale's President Bart Giamatti, the request for $9.3 million was finally approved. The installation of the new tank and its internal components began in May 1983 and was supervised by Richard Hyder. Many of the students felt that the experience they gained during the installation was of great importance to them and so there was none of the unrest that might have been expected from so long an interruption in the Yale nuclear program. Allan and his colleagues were able to begin operation of the new Extended Stretched Trans Uranium 1 (ESTU-1) accelerator in 1987 and were able to obtain 22.7 MV on the terminal.

Around this time Yale assistant professor Moshe Gai showed that the cold fusion results reported by Pons and Fleischmann of the University of Utah were in fact due to cosmic-ray secondary neutrons being scattered from the material in the Utah cells and had nothing whatever to do with a nuclear fusion process. This was one of the important experiments terminating the wild enthusiasm for, supposedly, a new source of essentially free energy.

Harry Gove, Ted Litherland, and Ken Purser did extensive work with Peter Parker's system, developed at Yale, on the measurement of very long lifetimes through detection of long-lived isotopes, and they demonstrated that the Shroud of Turin was not the burial shroud of Christ.

THE DUTIES OF THE LABORATORY DIRECTOR

During his years as director of the laboratory, Allan spent at least 30 percent of his time recruiting new faculty members and finding positions for graduate students following completion of their work in the laboratory. His goal was to have something like a third of them in academic positions, a third in industrial ones, and a third in government and other activities. If all the graduates had wished to be academic nuclear physicists, Allan would have considered it a substantial failure.

In 1983 Allan underwent open heart surgery. He contracted the infection serratia shortly thereafter. This is an infection from which no human had ever survived previously. After Allan's doctors had told his family there was no hope that he would live, Allan's family brought in the brilliant plastic and reconstructive surgeon Irving Polayes. After several more surgeries and a 10-week stay in the hospital Allan was again on the road to recovery.

HONORARY DEGREES

Allan: "One of the very pleasant aspects of the academic life is the acquisition of honorary doctorates from other universities." His first honorary degree was awarded by the J. W. Goethe University of Frankfurt am Main, Germany. Allan: "[A]nd my good friend Walter Greiner, a brilliant and distinguished theorist with whom I have worked throughout my career, at various times, I am sure had much to do with this honor."

In 1981 he was awarded an honorary degree by the University of Strasbourg and in 1983 by his alma mater Queen's University in Kingston, Ontario. "Having already held a B.Sc. and an M.Sc. degree from Queen's it was a particular pleasure to receive the D.Sc. and as many others have mentioned to me there is again something very special about this kind of recognition when given by your own university."

THE U.S. NATIONAL MEDAL OF SCIENCE

In 1988 Allan was awarded the U.S. National Medal of Science by President Ronald Reagan—the highest honor available to a scientist in the United States. The citation reads:

> For seminal work on nuclear molecules, for development of tandem accelerators and semi-conductor detectors for charged particles, for his contributions to particle-gamma correlation studies, and for his role in founding the field of precision heavy-ion physics.

While at Yale, Allan served on numerous boards of directors and on many scientific advisory boards. He was appointed to the National Science Board, the body of the National Science Foundation that advises and shares policy-making authority with the director. In 1980 he was elected vice president of the American Association for the Advancement of Science, the world's largest scientific society and moved up to the presidency in 1981 and to the chairmanship of the board in 1982.

FURTHER CONTRIBUTIONS TO PUBLIC POLICY: THE REAGAN AND GEORGE H. W. BUSH ADMINISTRATIONS

Allan Bromley was not only an outstanding nuclear physicist, he was also a model "civic scientist," a term one of the authors (N.L.) and others have used to describe an individual who not only contributes significantly to our understanding of the natural world but who also devotes much of his or her career to public service. The notion that scientists should be more involved with the public and the political process was emphasized over 30 years ago by a great champion of science in Congress, the late Congressman George Brown of California. Allan's career in public service culminated with his appointment by President George H. W. Bush (1989-1993) as assistant to the President for science and technology policy (the first person to hold that title), a Cabinet-level post with direct access to the President. He served simultaneously as director of the Office of Science and Technology Policy (OSTP), a Senate-confirmed position.

While in the White House, Allan oversaw a fivefold increase in both the staff and budget of OSTP between 1989 and 1993. He revitalized the Federal Coordinating Council for Science, Engineering, and Technology—the mechanism used to coordinate science and technology activities across the federal government—and he achieved an unprecedented level of cooperation and communication among the more than 20 federal agencies that support U.S. science and technology.

Allan was responsible for the first formal published statement of U.S. technology policy and played a central role in expanding cooperation between the federal government and the private sector toward effective use of technology in U.S. society. He believed that one of his major accomplishments during the George H. W. Bush Administration was the breaking down of the barriers that had existed between the federal government and the private sector in the area of technology development, a change that was long overdue. During the Bush Administration, Allan often testified before congressional committees and delivered more than 400 addresses to major audiences across the country and the world as the senior representative of U.S. science and technology. Allan found it a great pleasure to work for George H. W.

Bush: "George Bush is a man of deep personal principle and intrinsic honesty."

But long before holding these high-level White House positions, Allan was involved in science policy matters. His excellent book *The President's Scientists—Reminiscences of a White House Science Advisor* (1994) provides a personal account of his path to the White House and an insiders view of how the White House functions, at least the George H. W. Administration. In this section of the paper one of the authors (N.L.) will draw substantially from this source as well as the proceedings of the 2005 Yale Memorial Symposium in Honor of D. Allan Bromley (Fleury and Iachello, 2006) and other works referenced throughout the remainder of the paper.

Allan began his public and community service involvement in the manner of most scientists by serving on various review and advisory committees of federal agencies or the National Research Council. Allan immediately impressed those around him—on his side of the table and especially those on the other side—with his knowledge of physics, command of important information, ability to communicate with different audiences, and when appropriate, his well-honed skill at tough negotiations. He was increasingly sought out to chair important committees, lead delegations, make the case for science to policy makers, and accept positions of leadership in the science community.

Allan served as an adviser to the Nixon Administration, as mentioned earlier, and was tapped by President Ronald Reagan (1981-1989) to be a charter member of the White House Science Council (WHSC), which was chaired by former Los Alamos physicist George Keyworth (and William Graham, who succeeded Keyworth), science adviser to President Reagan. His work on the WHSC was focused on international issues (e.g., as chair of the Reagan-Ghandi

Panel on Indo-U.S. Cooperation in Science and Technology and of the Reagan-Sarney Presidential Panel on U.S.-Brazil Science and Technology Cooperation) as well as higher education and the national research laboratories (served as vice chair, with David Packard, of the panels on the Health of U.S. Universities and Colleges and on the U.S. Federal Laboratories).

On behalf of the National Academy of Sciences he organized a group of nuclear scientists to tour extensively in the People's Republic of China following the end of the tragic cultural revolution. He also hosted a large group of Chinese scientists who had been invited to visit the United States by the U.S. Department of Energy. As a result of this, a project somewhat similar to the Wright Laboratory was established at the Atomic Energy Laboratory in Beijing.

Allan also was appointed by President Reagan to the National Science Board (1988-1989) but had to resign when he was selected by President George H. W. Bush to join his White House team.

SCIENCE ADVISER TO PRESIDENT GEORGE H. W. BUSH

In 1989 President George H. W. Bush chose Allan to be his science adviser, with the title of assistant to the President for science and technology, a Cabinet-level post in that he was one of the President's senior advisers who had direct access to the President, and nominated him to be director of the Office of Science and Technology Policy (OSTP). He served in both these capacities until the end of the Administration in January 1993. This was the first time that the President's science adviser had held the title of assistant to the President. President Clinton adopted that practice as well.

Allan had come to know Vice President George H. W. Bush during the former's service on the Reagan White House Science Council. When the new ESTU-1 accelerator in the

Wright Laboratory was dedicated, Vice President Bush accepted Allan's invitation to give the keynote address. After George Bush was elected president he called Allan and asked him to join his Administration. Allan took a sabbatical from Yale, and he and his wife, Pat, moved to Washington, D.C., in 1989. Sadly Pat had been diagnosed with cancer just before this move and passed away on October 2, 1990.

During his 1989 interview with President George H. W. Bush, Allan being the seasoned negotiator that he was, made three requests: he would have access to the President whenever he felt that it was important to see him; once he and the President had agreed on a policy action in the area of science and technology, he would have the President's full support in making it happen; and that the four OSTP associate directors would be appointed (following Senate confirmation) by the President, as was permitted but not previously implemented by the 1976 legislation that established OSTP. Based on Allan's advice, as well as that of President Clinton's first science adviser (also assistant to the President for science and technology) and director of OSTP, Jack Gibbons, one of the authors (N.L.) received the same assurance (regarding access) from President Clinton, prior to moving to the White House as Gibbons's successor.

Former Governor John Sununu, who was chief of staff (1989-1992) during most of the time Allan was in the White House, was perhaps in the best position to observe how President George H. W. Bush's science adviser operated in the White House. In Sununu's presentation at the Yale Memorial Symposium, he pointed out that Allan was effective because he truly understood what the job of President's science adviser was and what it was not. The job is to give the President the best objective advice on any policy matter that relates to science and technology (e.g., global warming and climate change), summarize the state of scientific understanding—including all the uncertainties, and when appropriate recommend policy options. The job is not to be a representative of the science community or environmental community or any other group that might have a special interest in the policy outcome. Because most important policy matters involve not only science but also other issues (e.g., economic tradeoffs) the science adviser must work well with other advisers to the President and, whenever possible, reach agreement on policy recommendations before they reach the President's desk. Global climate change is a good example, where Allan's deep probing of the science and his ability to translate technical findings for nonscientists in the White House was enormously important in President George H. W. Bush's decision to sign the Framework Convention in 1992. Sununu gives Allan very high marks in all these areas and has nothing but strong praise for the job he did for President Bush and the nation (Fleury and Iachello, 2006, p. 16).

Allan possessed the necessary knowledge, experience, and personal skills to be effective in the White House. But he also had the important advantage that he knew President George H. W. Bush personally. That relationship grew even stronger during the time Allan was in the White House, as President Bush noted in his warm remarks (video presentation) at the 2005 Bromley Memorial Symposium (Fleury and Iachello, 2006, p. 13). These comments are fully consistent with a private conversation one of the authors (N.L.) had with President G. H. W. Bush (personal communication, 2002). Here's what President Bush told the symposium attendees:

> I want you all to know that I held Allan Bromley in the highest regard. My respect for the job he did as Science Advisor to the President knows no limits. He was an especially effective advisor who advanced an ambitious agenda for science and technology...he helped me give science and technology a

much needed enhanced visibility among our nation's priorities. And, while accomplishing all of this, Allan Bromley remained a decent, nice man" (Fleury and Iachello, 2006, p. 13).

It is not possible to describe in detail Allan's many accomplishments during his time as science adviser: many were his deft handling of unanticipated questions, events, and minicrises that were not documented but nonetheless were very important. In broad terms the topics he dealt with include research and development; Superconducting Super Collider; K-12 and higher education; economic competitiveness; regulation; new technologies and technology transfer; computing and communications; environment and climate change; energy; nuclear waste; health, medicine, and quality of life; food safety; space science and exploration; national security and missile defense; weapons of mass destruction; transportation; international research cooperation; and many others.

What follows are selected examples of contributions that one of the authors (N.L.) considers illustrative of how Allan worked in the White House and of his effectiveness as science adviser to the President.

INTERAGENCY RESEARCH INITIATIVES: THE ROLE OF THE FEDERAL COORDINATING COUNCIL FOR SCIENCE, ENGINEERING, AND TECHNOLOGY

Allan considered his greatest accomplishment the reinvention and strengthening of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) and, related to that, the Office of Management and Budget (OMB) multiagency budget crosscuts that show what the federal government is spending in an area like global climate change (1994, p. 43, chap. 6; Smith, 1992, p. 179). The purpose of this committee is clear from its title, but it was Allan's view that to be effective the committee would need to be at the highest level, with agency officials who could commit to policy actions, including budget allocations.

By getting the President's agreement and the help of the President's chief of staff, John Sununu, Allan was able to raise the level of FCCSET, chaired by Allan as science adviser, so that Cabinet secretaries (or deputy secretaries) and heads of major independent agencies (NSF, NASA, EPA, CIA) and the OMB would be at the table.

With OMB and the heads of all the relevant agencies in agreement on science and technology directions and budget priorities, and armed with the OMB budget crosscuts, Allan was able to direct a significant portion of the federal R&D funding toward specific presidential R&D initiatives, centered on strategic areas that addressed vital national needs and required substantially increased research investment. Six crosscutting initiatives were identified for the first three years of the Administration: Global Climate Change Research; High Performance Computing and Communication; Advanced Materials Science and Processing; Biotechnology; Mathematics and Science Education; and Advanced Manufacturing.

If a Cabinet secretary or agency head began to have doubts, a brief conversation with the President would remove any uncertainty. From the agency's perspective, there were opportunities and risks. If Congress went along with the President on an initiative and additional funding was appropriated, the agency's budget would get a piece of that. If Congress disagreed, funding could be cut in the area of the initiative, and the agency could lose money and budget flexibility. With the President's strong support and Allan's negotiating skills, several of the initiatives were very successful. Some of these were modified and continued into the Clinton

Administration, which adopted the coordination model of FCCSET but transformed it into the National Science and Technology Council (NSTC), chaired by the President. The NSTC was of critical importance in the planning the National Nanotechnology Initiative (NNI), which continues to receive the strong support of the White House and Congress.

RESEARCH BUDGETS

Allan was a strong advocate for increased federal research funding, but he understood that policy makers needed to be able to connect that research with potential benefits in a way that was easily understood. Strategic initiatives did just that, and by keeping them sufficiently broad in scope there was plenty of room for excellent basic research in all areas of science and engineering to be supported. Indeed, while the theme of competitiveness was prominent in President G. H. W. Bush's first state of the union address, the President pledged to increase research funding for the National Science Foundation (NSF) "to promote basic research and keep us on track to doubling its budget by 1993."[1] Allan's strategic approach was employed by President Clinton's science advisers (John Gibbons and Neal Lane) as well. For example, the NNI was a strategic initiative focused on nanoscale science and engineering research that provided the rationale for a larger budget initiative that emphasized research in all the physical sciences and engineering. One of the authors (N.L.) recommended that package to President Clinton, who included it in his fiscal year 2001 budget request; the increase for NSF was nearly double the largest dollar increase the NSF had ever received.

After leaving the federal government, Allan did not hesitate to speak out when he thought science policy was moving in the wrong direction. In 2001 he coauthored a strongly worded opinion piece in *the New York Times*, followed two years later by a longer article analyzing the previous decade of federal research funding and criticizing the incoming G. W. Bush Administration on its treatment of science and engineering research in the President's fiscal year 2002 budget outline, which was contained in President G. W. Bush's "A Blueprint for New Beginnings,"[2] sent to Congress on February 28, 2001, and the President's budget requests for the early years of the Administration. In the same article he credited the Clinton Administration, especially in its fiscal year 2001 budget request, for its strong support for large increases in research funding (2003). In the latter part of the second term of the G. W. Bush Administration the President did request significant budget increases for NSF, the Department of Energy's Office of Science, and the National Institute of Standards and Technology, as recommended by the National Research Council report *Rising Above the Gathering Storm* (NRC, 2007). In addition, Congress with strong bipartisan support passed and President G. W. Bush signed the America Competes Act, which also stressed the importance of increasing research support. Although disagreements between Congress and the G. W. Bush Administration resulted in the increases not being appropriated, the need for future action is now well understood at the highest levels of government. Allan's early attention to the nation's need for increased research investments in the physical sciences and engineering and his subsequent activities (e.g., with the American Physical Society) undoubtedly had much to do with these positive developments.

INDEPENDENT, OBJECTIVE EXTERNAL ADVICE FOR THE PRESIDENT / ROLE OF THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

Over the years several Presidents have had external advisory committees (e.g., the President's Science Advisory

Committee, which was so effective during the post-Sputnik period of the Eisenhower Administration), but the council fell out of favor with President Nixon when members of the council publicly criticized his policies on such matters as the Supersonic Transport. Nixon abolished the PSAC and accepted the resignation of his science adviser. President Ford did not appoint a new council, although he did reestablish the science adviser's position and signed legislation establishing the Office of Science and Technology Policy, with a Senate-confirmed director, in the White House. President Reagan also did not want a PSAC reporting to him. But he did appoint an external committee, the White House Science Council (WHSC), reporting to his science adviser, G. Keyworth. Allan Bromley served on the WHSC but felt it would have been more effective had it reported to the President. Thus, when Allan joined the G. H. W. Bush Administration, he recommended the formation of a new committee of distinguished individuals with diverse backgrounds, including industry, to be appointed by the President. Thus was born the President's Council of Advisors on Science and Technology (PCAST), which was chaired by Allan and reported to President Bush. The Council held monthly meetings, sometimes attended by the President, drafted reports, reviewed FCCSET reports before being sent to the President, and responded to presidential requests for information.

THE DEMISE OF THE SUPERCONDUCTING SUPERCOLLIDER

One of Allan's great disappointments was the vote by Congress to kill the Superconducting Supercollider (SSC), which was to be built in Texas, near Dallas. Much has been said and written about the reasons behind that event. Allan summed up his analysis by noting that a request for Japanese participation and funding ($1.5 billion was expected) was taken off the President's agenda, for political reasons, in his last trip to Japan and replaced by discussions with the "big three" U.S. automakers. In Allan's words: "This lack of significant foreign participation in the SSC construction, together with the fact that the estimated cost of the project had increased from its original $4.5 billion to at least $11 billion in 1992…were in my opinion, the two most compelling reasons why the Congress in 1993 terminated support for the SSC" (1994, p. 213).

THE BIRTH OF A FEDERAL TECHNOLOGY POLICY

It is notable that "technology" was included, for the first time, in the name of the President's external committee of advisers, thus signaling that the G. H. W. Bush Administration would have an interest in technology as well as science. Republican administrations had shied away from anything that looked like industrial policy, and this sounded close. But technology was a priority for Allan, who has often remarked that he took seriously the "T" in OSTP, and technology figured prominently in the agenda of the G. H. W. Bush Administration, which issued a report titled *U.S. Technology Policy*, with the presidential seal of a Republican President on its cover. The report, which addressed issues such as the workforce, financial environment, technology transfer, and legal matters, provided a basis for the development of a number of initiatives, including the development of precompetitive and dual-use technologies in partnership with industrial sectors.[3] Allan was justifiably proud of the G. H. W. Bush Administration's success in helping to bridge the attitude gap between the federal government and the private sector on the respective roles in matters of precompetitive technology.

The G. H. W. Bush Administration was clear that technology policy was not the same as industrial policy, emphasizing that the federal government should not pick winners and losers in the marketplace. Even so, Allan got considerable resistance from others in the White House, which he fended off with the support of President Bush and John Sununu.[4] Mary Good, former undersecretary for technology, Department of Commerce, in her presentation at the Yale symposium, described in detail the important advances made by the G. H. W. Bush Administration in technology policy and commented on the influential role Allan played, remarking that "the policy encouraged the timely translation of research results into commercial products or services. Dr. Bromley, perhaps more than almost any basic scientist I've ever known, understood this necessity" (Fleury and Iachello, 2006, p. 42).

STRENGTHENING INTERNATIONAL COOPERATION—THE ROLE OF THE CARNEGIE G-8 GROUP

Allan often expressed his frustration with the State Department's apparent disinterest in science and international cooperation on matters of science and technology (Greenberg, 2001, p. 318).[5] Unable to get help from the State Department, Allan decided to proceed on his own. With some private funding Allan founded the "Carnegie Group," an unofficial meeting of the science and technology ministers and their counterparts in the G-8 countries (plus Russia) usually held twice a year in one of the host countries. Allan recognized that to make progress with science and technology (S&T) cooperation at the highest levels of government, the top S&T officials would need to know one another and have a chance for off-the-record conversations—with no staff, no official record, no press releases—well before any formal actions were taken. This was a powerful notion, and Allan accomplished the feat by enlisting the help of the late Bill Golden and getting early support from the Carnegie Foundation (1994, p. 205). The Carnegie Group continues to meet and, at least in the experience of one of the authors (N.L.), has proven to be very effective.

This nation has been well served by the many scientists who have advised the U.S. government, including science advisers to the President. Each individual who serves in this way experiences unique circumstances set by the times, the most pressing needs of the nation, and the priorities and style of a particular President and Administration. Allan was the right person at the right time. Allan Bromley possessed just the right balance of intellect, insight, creativity, charm, and assertiveness that enabled him to be effective in Washington. John Marburger, science adviser to President G. W. Bush, in his presentation at the Yale symposium remarked, "Allan Bromley's willingness to dedicate much of his life to the improvement of science policy formation will make it easier for others to follow his example" (Fleury and Iachello, 2006, p. 71).

THE YALE ENGINEERING YEARS: 1994-2000

Despite numerous offers to go elsewhere, when President Bush left office Allan returned to Yale in January 1993. Upon his return Yale created for him the first and only Sterling Professorship of the Sciences. Early in 1994 Allan agreed to become the dean of engineering at Yale. He hired Mrs. Sarah Scubas as his executive assistant. "I could not have asked for a more competent individual with superb interpersonal skills and a detailed knowledge of the university." Early on, Allan established two main goals for engineering: first, to get more Yale students into engineering and more engineering into all Yale students. Second, to produce engineers that would be in the top 10 percent worldwide. Allan totally revamped the entire course offerings and the faculty recruiting policy. In addition, he created the Sheffield Fellowship Program and the

Sheffield Distinguished Teaching Award. Allan also focused on rebuilding corporate recruiting in engineering.

In 1996 the members of the American Physical Society (APS) voted to elect Allan as vice president, president in 1977, and past president in 1997. Over a decade earlier Allan had helped to establish the APS Division of Nuclear Physics (1966). The APS awarded him its 2002 Nicholson Prize in recognition of his roles as research scientist, outstanding teacher, supportive mentor and colleague, leader of the physics community in his country and worldwide, and adviser to governments.

THE IMPORTANCE OF CONSULTING

Allan was convinced that consulting on the part of his academic faculty members enlivened both their teaching and research activities by giving them a broader view of their individual fields. In Allan's case, because of his service on a great many boards of directors and consulting with most of the nation's laboratories and many corporate laboratories, he had the opportunity to see just how important this activity can be and consequently as dean strongly encouraged his faculty members to undertake consulting activities wherever and whenever possible.

THE IMPORTANCE OF ENDOWED PROFESSORSHIPS

One of the most important items in a university's arsenal when attempting to recruit senior scholars is the availability of endowed professorships. As a result of the monies that Allan was able to attract from alumni and other donors for such purposes, in January 2000 the president of Yale committed to expending $500 million for the production of new facilities and buildings for the physical sciences and engineering. This was followed by an equivalent commitment for facilities and buildings for the Medical School for a total of $1 billion.

Allan's original appointment as dean was for four years to end on June 30, 1998, but at the president's request Allan continued for an additional two years.

EPILOGUE: 2000-2003

After leaving the dean of engineering position at Yale, Allan spent much time in his office in the Wright Nuclear Structure Laboratory, writing several books, including *A Century of Physics* (2001) and his memoirs. Early in 2001 he was invited to be the first Yale Sheffield fellow.

At the request of President George H. W. Bush, Allan was involved in George W. Bush's campaign, identifying issues and responding to various questions. However, "This channel immediately closed after the election because the senior Bush was understandably reluctant to interfere in any way with his son's Administration or its assembly."

At the same time Allan agreed to serve as a commissioner on a detailed study on science and national security for the White House in 2001. In 2002 he worked with the Canadian Foundation on Innovation to select the seven individuals worthy of receiving the honor, visibility, and cash that the awards from that group convey.

During the early months of 2001, Allan came to the conclusion that the George W. Bush Administration's approach toward S&T was totally untenable. With considerable sadness but compelled by conviction, Allan wrote the opinion piece, mentioned earlier, for the *New York Times* that appeared on March 9, 2001, and contained the message, "No science, no surplus." This is an important document, as it conveys that Allan prioritized science and the future prospects of the world over any of his own political considerations.

Allan's first granddaughter, Jennifer, was born to his son, David, and his wife, Lynne Parshall, in 1986. David's other daughter, Sarah, was born in 1990. Allan's only grandson, Skylar, was born to his daughter, Lynn, and her husband, Peter Cohen, in January 1995.

CONCLUSIONS

The authors believe that Allan should have the last word.

> Let me conclude by emphasizing that I have thoroughly enjoyed my more than 40 years as a member of the Yale faculty. I have been remarkably well treated, I have been given every opportunity to do the research and teaching that was of greatest interest to me, and I have had the opportunity to engage in a very large array of interesting activities from my Yale base. Beyond question, Yale is one of the world's great universities. I would be remiss were I not to emphasize my firm conviction that every successful American has a very real obligation to give something back to the Nation that has offered him or her the opportunity to be successful.
>
> I have been extraordinarily fortunate to have lived during one of the most exciting and productive periods in science and in technology, my areas of primary interest, and I have had the opportunity to participate in my own research activities, in leadership in some of the most senior professional organizations in my field, and in the evolution of public policy toward making the new scientific and technological results available to, and important to, the lives of all humans.

NOTES

1. President G. H. W. Bush's first state of the union address to Congress. At en.wikisource.org/wiki/George_Herbert_Walker_Bush's_First_State_of_the_Union_Address. Accessed May 18, 2009.
2. President G. W. Bush's "A Blueprint for New Beginnings" sent to Congress, Feb. 28, 2001.
3. The Cooperative Research and Development Agreements involving federal laboratories and various industries represented one response to the policy. Another was the NIST Advanced Technology Program, which was continued by the Clinton Administration but was routinely attacked by many Republicans in Congress. The stated goal of the G. H. W Bush Administration's technology policy was to make the best use of technology in achieving the national goals of improved quality of life for all Americans, continued economic growth, and national security.
4. The discussions leading up to this policy statement also brought up the age-old debate about basic and applied research. Unwilling to accept various definitions of these categories, Allan and the OSTP agreed on other categorizations: fundamental research (to build on a core of knowledge); strategic research (to build a base of knowledge and skills in areas of evident interest to a broad class of users, not only scientists); directed research (focused on gaining knowledge for particular missions, products, processes, or services). That said, the federal government continues to keep their books with three columns: basic research, applied research, and development.
5. This frustration continued into the Clinton Administration, with Jack Gibbons expressing the same feelings. Finally, late in the Clinton Administration, Secretary Madeline Albright, guided by a report of the National Academies, appointed Norman Neureiter as science adviser to the secretary of state; he continued into the G. W. Bush Administration and was very effective in injecting science back into important international policy matters.

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