IN MEMORIAM

MERLE ANTONY TUVE

1901 — 1982

Merle A. Tuve, founder and first director of the Applied Physics Laboratory, died on May 20, 1982 after a long illness. A number of his former friends and colleagues contributed a small bouquet of remembrances of the lasting impressions that he made on them. Many others, too, will remember him with great affection.

On June 13, 1950, the honorary degree of Doctor of Science was presented to Dr. Tuve at commencement exercises of The Johns Hopkins University on the plaza in front of Gilman Hall. Dr. Ralph E. Gibson read the citation and presented Dr. Tuve for the degree to President Detlev W. Bronk:

> On behalf of the Faculties of the University, I have the honor to present as candidate for the degree of Doctor of Science, honoris causa, a scientist and leader of scientists, a bold adventurer in thought and action.
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> Of Norwegian descent, he came as a graduate student to Johns Hopkins by way of South Dakota, where he was born, and Minnesota, where he obtained his first degrees, bringing with him a lively and enquiring mind, a Viking spirit eager to accept Nature's challenges, to implement his vision in his conquest of the unknown, and for nearly a quarter of a century has led a group of investigators at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, of which he is now the Director. To him and his band of adventurers no region of the heavens nor the earth has been inaccessible, no challenge impossible. They pioneered in the experimental study of the ionosphere on the outer fringes of the earth's atmosphere. They delved into the innermost recesses of the atom to measure the short range forces between protons — an achievement which has been described as "a series of studies which is perhaps the most satisfying in the whole subject of nuclear physics." He is now leading an experimental investigation to discover the deeply buried secrets of the interior of the earth.
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> Long before the crisis broke on December 7, 1941, he realized the dangerous implications of the international situation and gathered together a group of scientists to strengthen the hands of our defenders. They chose a task which was considered by many to be well-nigh impossible — the development of radio proximity fuzes for shells. Their success has won a permanent place in the annals of this nation. As a feat of leadership alone, it has few parallels in history.
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> In peace, as in war, the calls of public service never fail to arouse his interest. He frequently leaves his laboratory, or his study, for the conference room to address himself to problems of public welfare. With a deep understanding of the ways of men, he brings to any worthy enterprise a sweeping disregard for nonessentials, a relentless determination to reach the goal, an infectious enthusiasm and gay spirit of adventure which sweep away the clouds of confusion and indecision, clearing the atmosphere for incisive thought and decisive action.
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> Mr. President, we take pleasure in presenting Merle Antony Tuve for the degree of Doctor of Science.

Lawrence R. Hafstad

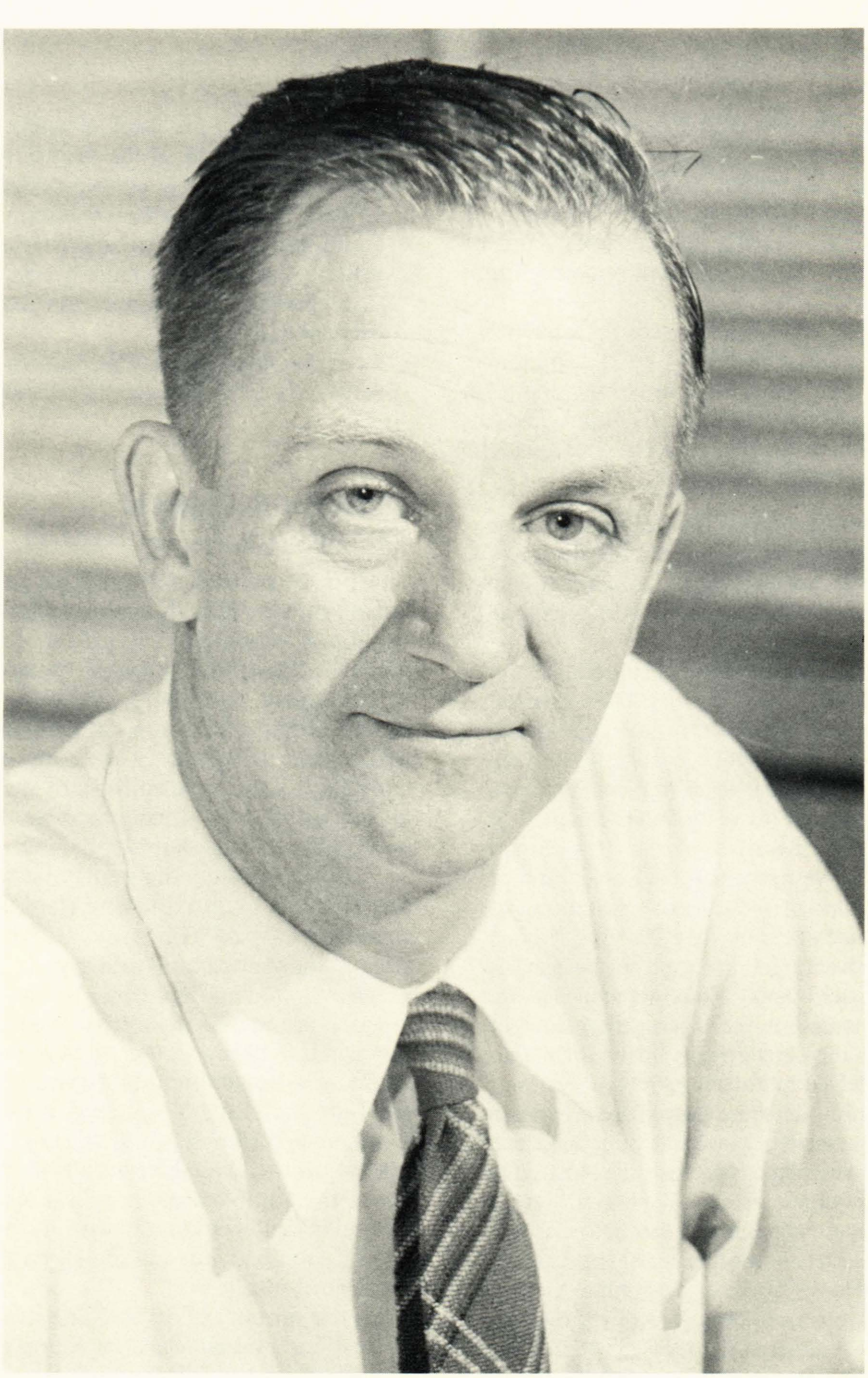
APL, 1942-1948; Director, 1946-1948

All of those who worked with and for Merle Tuve during the war quickly realized that he was a truly exceptional person. He was gifted in so many different ways: he was knowledgeable, imaginative, technically competent, articulate, inspiring, a good listener, self-confident, encouraging, sympathetic, dedicated, and a hard driver, all at the same time or, more accurately, as the occasion might demand. Merle was all of that at APL during the war. It did not happen overnight. He was that way before.

I can fix precisely the year I met Merle Tuve. In the fall of 1922, I started taking electrical engineering at the University of Minnesota. It was Merle who persuaded me that I could and should start with it. This was the first great debt I owe to him.

I had graduated from high school in 1920 and had particularly enjoyed the physics course, which had given me a beginning understanding of things electrical that had long fascinated me in those days of homemade radio sets. As a result, I was happy to take a job with Northwestern Bell to test and troubleshoot the complicated electrical circuitry of the new dial telephone systems. I enjoyed the work thoroughly, for each day was like being paid for working out crossword puzzles.

By the summer of 1922, I had become an old-timer in this field. When Merle, a young graduate from the University, was hired by the telephone company for the summer, he was assigned to work with me. For us it was a happy arrangement. I taught him the jargon of the telephone business and he gave me free tutoring in a freshman electrical engineering course. With this encouragement, by the end of the summer I was determined to get an engineering degree no matter how long it took. I switched from the daytime shift to the 3 to 11 PM swing shift at the telephone exchange.



MERLE ANTONY TUVE

Merle went on to graduate work at Yale and Princeton, so we lost contact. After getting my bachelor's degree, I started graduate work in physics and then was hired away by Bell Laboratories to work on the then-emerging field of transatlantic telephony. Years later, as a complete surprise, I received a letter from Merle telling me about his ionosphere work with Gregory Breit at the Carnegie Institution of Washington and saying he would like me to join them as an assistant. Since this fitted beautifully with the transatlantic telephone work at Bell Labs, I was given a leave of absence to work with Breit and Tuve at the Department of Terrestrial Magnetism in 1928.

The new job opened up a whole new world for me. It was essentially a switch from an engineering approach to one of basic science. It was indeed a privilege for me and a second great debt I owe to Tuve.

The decade of the thirties was a golden period in physics. Exciting advances were reported in each weekly issue of *Nature, Naturwissenschaften,* and *Comptes Rendues*. The Washington Physics Colloquium was the mechanism for keeping up with the progress. It was a small but dedicated group of people from the National Bureau of Standards; the Department of Agriculture; the Carnegie Institution of Washington's Department of Terrestrial Magnetism and Geophysical Laboratory; the Naval Research Laboratory; and the local universities.*

Breit and Tuve were active in keeping this unique group of people together and up-to-date on developments in the then-modern physics. Somehow, the top physicists of the time were persuaded to report on their work to this group of only a dozen or so people. This enabled our small group to get to know on a personal basis the leaders in the burgeoning field of physics at that time.

A very major contribution to physics was made by Tuve when he persuaded President Cloyd H. Marvin of George Washington University to set up a Chair of Theoretical Physics and then persuaded George Gamow to be the first incumbent. This led to a steady stream of distinguished scientists from both the United States and abroad to visit Gamow and incidentally to report to the Washington Physics Colloquium.

Tuve made a second great contribution to physics when he persuaded both the Carnegie Institution of Washington and George Washington University to finance, at intervals, a Theoretical Physics Symposium, which attracted all of the then-small number of leading workers in this specialized field. It was after one of these that Hans Bethe published his classic paper on the nuclear reaction in the sun. At another it was the report by Niels Bohr on the splitting of the uranium atom in Germany that led to the prompt confirmation of this process at both Columbia and the Department of Terrestrial Magnetism.

As to Tuve's personal work, I mentioned the ionospheric work. In my opinion, the work of Breit and Tuve came close to winning a Nobel Prize. The Appleton report on the measurement and confirmation of the existence of the theoretically predicted Kennelly-Heaviside Layer as an explanation of the skip-distance effect of radio waves by essentially a refraction technique was just a bit ahead of that of Breit and Tuve with their pulse technique.

Breit and Tuve entered very early into the high-energy physics field, moving toward the artificial disintegration of chemical elements. Since Lord Rutherford had used alpha particles of some 5 million electron volts of energy, Tuve and Breit chose to attain very high voltage by other routes. They were successful when the Van de Graaff generator concept came along.

However, Cockcroft and the Cambridge group had chosen the route of cascading AC transformers, which gave unlimited power, but by which it was hard to reach really high voltages. The break came when the theoretical explanation of radioactive decay was made on the basis of the statistical probability of potential barrier penetration. This made high current at moderate voltages the equivalent of small currents at very high voltages. The Cambridge group provided the first confirmation of the prediction of this theory and received a well-deserved Nobel Prize. It was a second close encounter for Merle Tuve.

Then, as both theory and technology advanced, the importance of quantitative knowledge about nuclear force fields increased. This led Breit and Tuve to tackle the tricky problem of trying to measure with precision the distance from the center of a proton at which the repulsive inverse-square electric field begins to be modified by the strong attractive nuclear field. In the vernacular, this would be to measure with precision the size of a single proton. In this, too, Merle Tuve was successful in the long series of proton-proton scattering measurements. It was recognized as a major contribution by the theoretical physicists of the period, but it was just one of many exciting discoveries of that time. It was certainly a Nobel Prize-scale contribution.

This, then, was the background of achievement that Merle had when he undertook to rescue the U.S.

*Several of the participants of the Washington Physics Colloquium had notable careers during and after World War II:

Samuel K. Allison, Director, Institute for Nuclear Studies, University of Chicago; *Gregory Breit*, Professor of Physics, Yale University; *Ferdinand Brickwedde*, Chief, Power Division, National Bureau of Standards; *Lyman Briggs*, Director, National Bureau of Standards; *Paul D. Foote*, Director of Research, Gulf Oil Corporation; *Ralph E. Gibson*, Director, Applied Physics Laboratory; *Lawrence R. Hafstad*, Director, Applied Physics Laboratory, and Director, General Motors Research Laboratory; *Sterling B. Hendricks*, Chief Scientist, Mineral Nutrition Pioneering Research Laboratory, Department of Agriculture; *Karl F. Herzfeld*, Professor of Physics, Catholic University of America; *Edward O. Hulburt*, Director, U.S. Naval Research Laboratory; *Joseph Kaplan*, Director, Institute of Geophysics, University of California at Los Angeles; *Louis R. Maxwell*, Chief, Applied Physics Department, U.S. Naval Ordnance Laboratory; *Edward Teller*, Director, Lawrence Livermore Laboratory; *Merle A. Tuve*, Director, Applied Physics Laboratory and Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington; *Harold C. Urey*, Professor of Chemistry, Columbia University.

Navy from the threat of air attack. The rest is history.

How can one summarize the accomplishments of a man like that? I had that task once before, when I was proposing Merle for membership in the Cosmos Club. At that time, I concluded my report with the statement, "Merle Tuve is a congenital and incurable sparkplug in the American physics scene." He certainly was, and he is sorely missed, but will long be remembered.

C. K. Jen

APL, 1950-1974; Vice Chairman, Research Center, 1958-1974

I first became acquainted with Merle Tuve in the fall of 1928 when I was a graduate student in the Moore School of Electrical Engineering of the University of Pennsylvania and he was a scientist on the staff of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Our connection was made through a collaborative research project on the ionosphere (then known as the Kennelly-Heaviside Layer). G. W. Kenrick (on the Penn faculty) and I did experimental observations at the Moore School in much the same way as Tuve and Lawrence Hafstad, at the Department of Terrestrial Magnetism in collaboration with the theorist, Gregory Breit. The observation at each station involved receiving pulsed radio frequency shortwaves transmitted at a frequency of 4435 kilohertz by station NKF of the Naval Research Laboratory.

We usually received in Philadelphia three sharp pulses, one of which was due to the ground wave and the other two from delayed multiple reflections from the ionized layer. The "virtual" height of the reflecting layer h was simply calculated as $h = c\Delta t/2$, where c is the velocity of light and Δt is the observed time interval between two adjacent pulses.

The fact that the radio wave was, in reality, refracted within the ionospheric layer instead of being reflected was made easily understandable by the famous Breit-Tuve Theorem, which stated that the time required for the wave to traverse the assumed triangular path by perfect reflection is equal to the time for the wave to trace out a curved path by refraction. Thus, the experimental observation could yield the virtual height of the layer, which can be correlated to the true height once the functional form of the index of refraction is known. We compared our Philadelphia results with those of Tuve and Hafstad in Washington and found them in satisfactory agreement. These findings, under the leadership of Tuve, led directly to the verification of the speculated existence of the Kennelly-Heaviside Layer. Because Tuve was the first person to exploit the pulse-echo method, he well deserves the honor of being recognized everywhere as the pioneer for the subsequent development of radar.

Tuve was, however, not alone in proving the existence of what we now call the ionosphere. Almost simultaneously, E. V. Appleton in England led a team of high-powered scientists in investigating the ionospheric properties through the interference of continuous waves, with which Appleton independently proved not only the existence of ionospheric layer(s) but also the amazing properties of this earth-bound magnetosphere.

Tuve's creativity in this ionosphere work can be said to be matched by his leadership of a group of brilliant scientists (G. Breit, L. R. Hafstad, R. B. Roberts, and others) in using a simplified yet improved Van de Graaff generator to demonstrate the identity of the proton-proton and the proton-neutron force. I made a special visit to the Department of Terrestrial Magnetism from Harvard University and saw this outstanding work while it was going on. Scientifically, this celebrated finding, announced in 1935, was recognized by Breit *et al.* to be an exceedingly important nuclear property and prompted the famous Yang-Mills theory on the conservation of isotopic spin and isotopic gauge invariance, a very great breakthrough for the theory of elementary particles.

Lastly, I wish to relate a heartwarming personal experience with Merle Tuve. In about 1952, approximately two years after I joined the Applied Physics Laboratory and six years after Tuve left his APL directorship, he happened to see a short abstract of a paper of mine in the Bulletin of the American Physical Society on the rotational magnetic moment of water vapor when in a particular rotational state. I believe he was led to think that even ordinary water (always considered as nonmagnetic) could have a magnetic moment! My guess was that, as the Director of the Department of Terrestrial Magnetism, he wanted to know how and why water, the most abundant material on the terrestrial globe, could be said to have any magnetic property! He almost immediately called me up and came to visit me in my small laboratory at the old "8621" site of APL. I greeted him warmly, showed him my experimental setup, and discussed with him what the paper was about. His sharp mind quickly sized up the situation and he immediately realized that I was only talking about a minute magnetic moment (on the same scale as the nuclear magnetic moments) of the H_2O molecule (or its deuterated counterpart species) in the rotational state.

It was hardly necessary for me to tell him that the rotation of the positive and negative charges in just about any molecule would result in a residual (i.e., not completely cancelled) magnetic moment. This can be qualitatively understood even with a classical picture. It became clear to him that this was an interesting "academic" problem, but devoid of most practical applications. I was hoping that Tuve was not terribly disappointed with this revelation. With his usual scientific curiosity and loving understanding of natural phenomena, I thought he was rather relieved that there were no surprises. My own feeling was that I was honored by his visit and by his expression that he was well pleased with it.

Joseph E. Henderson

Director Emeritus, Applied Physics Laboratory, University of Washington

The time was about one year before Pearl Harbor. We had all been friends since graduate school days and were in our academic jobs busy with teaching and research. We were fully aware of the war in Europe, but the United States was not involved and the political atmosphere was to avoid a war if possible. Without warning, a telegram came to the president of our university — a "Queen's command" — from Merle Tuve requesting our immediate leave from the university to prepare for the defense of our country. No details were forthcoming and the request was immediately granted, as the urgency was apparent.

We found that things were well organized when we arrived in Washington, D. C. The National Defense Research Council had been formed, and Section "T" was to be our base of operations. The "T" stood for Tuve, of course. The immediate problem was the defense of Great Britain against the powerful German air force, which was methodically pounding England, especially London, to rubble. Antiaircraft guns were surprisingly ineffective. Our task was to increase the effectiveness of the antiaircraft guns at least 1000-fold — and the proximity fuze was born.

Electronic components were the problem. For unlike the bombs, both the rockets and shells required new electronic structures — really rugged tubes. Here the genius of Merle and his small initial group had already paved the way with the electronics industry of the time, for only they could produce the huge quantity that would be required. Successful proximity fuzes were produced even before Pearl Harbor.

With Pearl Harbor we were in the war, and the need for trained and intelligent young men became paramount. Merle had seen that our graduate students back at the universities were the answer. Using Merle's original techniques, we brought them all to the various centers. The physicists of the country were organized for war, and the early weapons were in full development and production.

Not unexpected to Merle, and with these quick successes, all branches of the military came forth with their requirements; they now trusted the civilian scientists. Many of us returned to our original universities with projects suited to their locales, and new satellite laboratories were established at the California Institute of Technology; Princeton University; and the Universities of Texas, New Mexico, Michigan, Virginia, and Washington to serve the military needs of the nation.

A new and effective partnership had been born. I am convinced that this all was a part of the original scheme visualized and planned by Merle. He had seen the "big picture," and with his genius his scientists all became leaders in their fields. Many of the laboratories still exist and are the backbone of the nation's scientific defense. Such was the brainchild of Merle A. Tuve.

Ralph B. Baldwin

APL, 1942-1945; President, Oliver Machinery Company

Merle Tuve was a brilliant scientist. He accomplished much in several fields. But when World War II came, he and a few others were perceptive enough to realize that the nation's welfare depended on the development of new types of weapons and instruments. They all felt that we would be drawn into the war but could not afford to fight that war with World War I equipment. This small group of men, headed by Vannevar Bush, became the National Defense Research Council, with responsibilities in many fields.

It was Tuve's good fortune to be placed in charge of the proximity fuze program. It was the nation's good fortune that he accepted the challenge of "a job that couldn't be done." It was the good fortune of those who worked in his Section T that the effort was successful. The fuze worked. It did the job it was designed for. It shortened the war.

One of Tuve's first projects was to analyze the British antiaircraft defense system. This drove home very quickly the need for a proximity fuze because the British antiaircraft guns, with their time fuzes, were more effective in scaring off enemy bombers than in shooting them down. The American defenses were no better.

Tuve gathered together a varied group of men and women from many professions. He worked hard and saw to it that each of us also worked hard. On a recent occasion when I visited Merle at his home, we were chatting, when suddenly he showed a sensitive side of his nature. "I have always felt that I drove the lab personnel too hard, that I was too harsh." I hope that my reply comforted this ill and dying man. "You were dealing with a broadly diversified group. Many of them were prima donnas. Without strong leadership they would have pulled in too many directions. Your methods were exactly what was needed."

Tuve had a whole series of precepts. One of them was, "I don't want any damn fool in this laboratory to save money. I want him to save time." Another was "Shoot for an 80 percent job; we can't afford perfection. Don't try for an 'A'; in a war 'D' is necessary and sufficient, but an 'F' is fatal. Don't forget that the most perfect job is a total failure if it is turned in too late." These were the keys to successful wartime leadership.

Walter A. Good

APL, 1942-1977; Member, Principal Professional Staff

My first meeting with Merle Tuve was arranged by Dr. A. Ellett in the spring of 1941. I was in the final weeks of completing my Ph.D. at the State University of Iowa, where Ellett was my physics professor. He was on a mysterious leave to work at the Bureau of Standards in Washington, D.C. We graduate students guessed it was war work, but beyond that we had no idea what it was.

Ellett invited me to interrupt my dissertation preparation to visit the Bureau of Standards to consult on a "problem." This turned out to be a session with Dr. Hugh Dryden on the guided missile called Bat. I guess my radio-controlled model airplane experience was of more interest to him than my thesis on single crystals!

After the Dryden meeting, Ellett took me to another laboratory, the Carnegie Institution's Department of Terrestrial Magnetism, to meet Dr. Tuve. After a quick 10-minute discussion of radio-control model techniques, he signed me up for a job — to begin as soon as the Ph.D. was completed. At that moment, I had no idea what the job would be, but Tuve assured me it would be "interesting." The Ph.D. came on August 1, 1941, and I went to the Department of Terrestrial Magnetism on August 3, soon to find out that this was where the radio proximity fuze was being born.

I was fascinated with the tiny electronic parts and quickly went to work with Laury Fraser, Dick Roberts, and Jim Van Allen. This group got me up to speed in a short time, and I soon found myself as a team leader on the fuze time-delay clock. It was almost a week before I learned that there were two other teams on the clock problem!

Tuve had assigned three separate teams to the same job. We weren't supposed to talk to each other, but we did. We soon found that it was typical for Tuve to use multiple teams in this manner. Soon one team would be dropped as the others forged ahead. "We've got everything except time," Tuve would say. "If you need thirty clocks in a hurry, get thirty clockmakers to do the job."

Changing assignments seemed to happen about every six weeks in Tuve's shop. Since it was my first real job, I thought this was normal, but some of the older types thought it was a bit fast, even in wartime. Incidentally, the average age was around 30 years. I was 25 and getting $2100 a year.

While on the design and production of the tiny vacuum tubes with Van Allen, one of my jobs was to determine the acceptance parameters for the radio-frequency (RF) oscillator tube. This was a tough assignment because we found that separate electrical measurements on each tube would predict audio performance but not the RF capability. The practical solution was simply to put the fuze RF circuit in a black box, which would test each RF tube coming off the end of the production line. This raised objections because the RF frequency and circuit were classified as a military secret. But Tuve approved the practical solution and quelled the objections by requiring the inspector to place the black box in the safe each night!

Looking back on the fuze development period brings out the remarkable flexibility and adaptability of Tuve's methods of management. Even though he had ample funds and a variety of skilled people, he had a tough assignment with an extremely tight deadline. But Tuve pulled it all together — and on time.

F. C. Paddison

APL, 1942-present; Member, Principal Professional Staff

Merle was a very dynamic person, with a drive and intellectual curiosity rarely found together in one man.

In the early days of the Department of Terrestrial Magnetism's war effort, things had to change very quickly, as the staff was growing. New fuze applications continued to be developed. RCA, Sylvania, Eastman Kodak, Hoover, and Raytheon were in production, being fed by a pilot line at the respective plants and the APL development groups.

Results from Stump Neck, Dahlgren, Aberdeen, and then Newtown Neck arrived almost daily. Components arrived by the tens of thousands. Engineering of circuits, quality control of components assembly, sample sizes and statistics, 20,000 g's setback acceleration and potting were the words of the day. Torpedos, bomb fuzes, triodes, diodes, pentodes, beeswax, amplifiers, batteries, rear fittings, oscillators, and fuze projectile cases were everywhere.

At the end of almost every month, on Saturday night (and for many on Sunday night), you stopped — on the way to Dixie Pig for a beer — to check the organization chart to see where you would be working next month.

Merle kept it all moving; yet he always took time to stop and ask how things were going. He knew everyone by name, and we were all a large family.

When Merle Tuve returned to the Department of Terrestrial Magnetism after the war, we were all sorry to see him go; he left with our heartfelt good wishes and our thanks for having had the opportunity to know him and share in the enthusiasm and spirit he carried with him.

Harner Selvidge

APL, 1942-1945; Group Supervisor, Guidance

Merle Tuve profoundly influenced all those who worked closely with him during the war, and this influence stayed with many of us the rest of our lives in all our activities, whether academic or industrial. Nothing in his background would have led us to suspect that beneath the exterior of a research scientist was a raging tiger and hard-driving executive. He was truly the ideal man for the task, with an uncanny way of getting to the real heart of a problem, whether technical or personal. We had lots of good technical people, but the way he was able to handle the diversity of personnel with a myriad of backgrounds was a major factor in the success of the operation.

We looked with awe and respect at the way he was able to handle relations with our military customers, whose people he could not control, and to get the most out of our own people, whom he could. He had a keen insight into the capabilities of his staff, in many cases more than they had themselves. I remember vividly a discussion with him regarding the reorganization of the staff for the Talos program, which involved me. ''I've got to have some entrepreneurs,'' he said, ''and Selvidge, you're an entrepreneur.'' I could not have been more surprised if he had accused me of being a full-blooded Hottentot. I had always thought of myself as the academic researchy type. As the future proved, he was right. He usually was.

His principles of operation for the Lab have been widely quoted. They were absolutely right for that situation, but some would not be applicable except in wartime. In the 37 years since I left the Lab there are two of his maxims which I still quote and use on many occasions. The first was his response when we complained about the lack of qualified personnel to do a job: ''We've got to win the war with the people we've got!'' The other is the proper way to get what you want from organizations of any size, civilian or military: ''Deal with the higher echelons!''

The nation and those of us whose life he touched owe him a debt we could never repay. His memory will be with us always.

Wilbur H. Goss

APL, 1942-1965; Assistant Director, Technical Evaluation

During APL's years of existence, it has been distinguished by those who have known it as much by its spirit as by its many brilliant accomplishments. The living, free-thinking embodiment of that spirit, which has been so carefully nurtured by a succession of remarkable men who have served as directors, was Merle Tuve, the founder of the Laboratory some 40 years ago.

Only a relative few of us who served under Tuve during those early years remain, but so strongly felt was the impact of Tuve's leadership on all of us in those early years that as new members joined the team they, too, became imbued with that same dauntless spirit, infectious enthusiasm, and total dedication.

To Merle Tuve it didn't matter who you were; it was what you could do. And what you could do was magnified many times by the total support he gave those to whom he entrusted major responsibility. There were no alibis, because there were no limits imposed. A complaint that one's test units were not receiving the priority they deserved at the test field would be brushed aside by the challenge to set up one's own test field! The only limits were those that were self-imposed.

It was Tuve's inspired leadership, amid the challenges of a wartime emergency, that caused ordinary 6-footers to walk 12 feet tall, for the original staff of the Laboratory was certainly not trained for nor experienced in the task which they undertook and mastered. A sprinkling of college professors, some ''ham'' operators, some graduate students, some technical volunteers from the oil industry, and a host of others with a smattering of technical training but with willing hands and heart — that was the nucleus, almost totally without industrial background, from which Tuve fashioned a team that designed, developed, and tested the proximity fuze, then supervised in detail the vast industrial empire that produced hundreds of thousands of proximity fuzes every day, with their specially manufactured tubes, batteries, safety devices, etc. Those fuzes, in various adaptations, eventually found their way into nearly every type of artillery round of the American and British forces in World War II and played a major role in determining the outcome.

Merle was able to maintain an intimate awareness of the currently critical problems in major areas and the progress of the development efforts to solve them. It was not surprising, when working even in the late hours of the night, to find him dropping by to see what was going on. His office door was always open.

It was Merle Tuve who, in the later stages of the war, foresaw the coming of the missile age and set the stage for the development of the Naval missile family by initiating the Bumblebee Program at APL, with its pioneering concepts of propulsion and guidance and damage potential. Although recognition for the fruition of this program belongs to the leaders who so capably succeeded him, it was Tuve who set the initial goals and who set them high enough to ensure reaping the rewards which eventuated.

With all this said, perhaps the most memorable aspect of Merle Tuve was his warm, caring personality. To know him was to love him. He left an indelible mark on countless lives. I will never forget him.

T. W. Sheppard

APL, 1942-present; Associate Supervisor, Fleet Systems Department;

Those who worked with Merle Tuve carried away vivid, strong impressions of this great man. For many at the Applied Physics Laboratory, the early days of the VT fuze program not only created a spectrum of memories, but also had a profound effect on our professional lives. His approach to the challenges of national importance imbued his staff with a spirit, motivation and philosophy that permeated the Laboratory for decades.

The Department of Terrestrial Magnetism of the Carnegie Institution of Washington, the birthplace of the VT fuze, is situated on park-like land in northwest Washington, D.C. There, a scattering of buildings included a rather stately main building, the Van de Graaff Building, the Cyclotron Building, and others devoted to the research activities of that institution. Those who planned the Cyclotron Building for the conduct of scientific research would have been taken aback in 1940-42 when that building became the focal point for the VT fuze work, housing Dr. Tuve's office, laboratories, and shops. The Cyclotron Building is not large, and the admixture of types of facilities and staff, the fusion of scientists, engineers, technicians, and the director created many interesting experiences.

Many descriptors have been applied to Dr. Tuve in attempting to characterize him, and surely "dynamic" and "forthright" must rank high on the list. As a youth working in the fuze model shop just a few doors down the hall from his office, I was fascinated as his meetings audibly flowed out of his office and throughout all of the first floor. Many of us were unintended witnesses to the daily meetings where results were assessed, problems tackled, and directions given in no uncertain terms, with enough volume, color, and emphasis to make the point. Dr. Tuve was a determined taskmaster, always fair — but intolerant of anything except the highest possible performance from each person on the project.

The incongruity of the setting at the Department of Terrestrial Magnetism was matched when The Johns Hopkins University assumed responsibility for the project and the Applied Physics Laboratory began operations in a Chevrolet garage in Silver Spring. Although the facilities were larger and being rapidly expanded, the style and force of Tuve's leadership continued to be felt by everyone on the staff, from the highest to the lowest position. The thrusts of the staff were redirected continually to overcome the succession of problems impeding achievement of our goal: get a useful weapon into service in time to help win the war! There was rarely a day that somewhere in the building the banging of sledgehammers was not heard, creating piles of rubble and clouds of dust as walls were moved and rooms reshaped to support those redirected project thrusts. Dr. Tuve was a man of action, and he allowed nothing to stand in his way. Determination, innovation, inspiration, perspiration, technical talent — the list could go on and on with frail attempts at characterization.

Dr. Tuve was masterful in capturing the wholehearted dedication of all the staff and inspiring them to work with a vigor and capacity surprising even to themselves. A memorable part of this total participation involved keeping the staff abreast of the larger view of the project, including the results of early Armed Service use. There was no suitable meeting room at "8621," so the staff would troop across Colesville Road to the Silver Theatre on occasional mornings for classified meetings with the directors and high-level representatives of the Services and Government. On the theater stage, as well as in his office and throughout the spaces of the Laboratory, Tuve effectively practiced his principle of participative management. He dissolved the natural barriers separating scientists, engineers, and technicians and melded them into a cohesive force doing good and timely work in our nation's interest.

We cherish his memory and are grateful for having known him and served under his leadership.

Philip H. Abelson

Editor, Science, *American Association for the Advancement of Science*

Merle Antony Tuve (1901-1982) was truly a leading scientist of his times. He joined with Gregory Breit in the first use of pulsed radio waves in the measurement of layers in the ionosphere. Together with L. R. Hafstad and Norman Heydenburg he made the first and definitive measurements of the proton-proton force at nuclear distances. During World War II he led in the development of the proximity fuze that stopped the buzz bomb attack on London, was crucial in the Battle of the Bulge, and enabled naval ships to ward off Japanese aircraft in the Western Pacific. Following World War II, he served for twenty years as Director of the Carnegie Institution of Washington's Department of Terrestrial Magnetism, where in addition to supporting a broad program of research, he personally made important contributions to experimental seismology, radio astronomy, and optical astronomy.

Tuve was a dreamer and an achiever, but he was more than that. He was a man of conscience and ideals. Throughout his life he remained a scientist's scientist, one whose primary motivation was the search for knowledge, but a person whose zeal was tempered by a regard for the aspirations of other humans.

Merle Tuve was born in Canton, South Dakota, 27 June 1901. All four of his grandparents were born in Norway and had migrated to the United States. His father, Anthony G. Tuve, was President of Augustana College, and his mother, Ida Marie Larsen Tuve, was a music teacher at the college. A next-door neighbor and contemporary was Ernest Orlando Lawrence, later famous for development of the cyclotron. The two boys played together and at age 13 began to build telegraphic and later radio equipment. They were among the early radio amateurs.

After Tuve's father died in the influenza epidemic of 1918, the family moved to Minneapolis, where Merle attended the University of Minnesota, graduating in physics in 1922 and obtaining a master's degree in 1923. Following a year at Princeton, where he was an instructor, Tuve went to The Johns Hopkins University to work for his doctorate. While at Minnesota, Merle had developed a close friendship with Gregory Breit, a theoretical physicist who moved in 1924 to the Department of Terrestrial Magnetism. After Tuve's arrival at Johns Hopkins, Breit sought his collaboration in a possible effort to study the ionosphere. Naturally, Tuve was interested. He respected his friend, and the puzzle presented by Breit was related to his boyhood experiences with radio, because the long distance reception of radio waves implies their reflection from the ionosphere.

At the time, the electronics equipment available was primitive and relatively insensitive. To demonstrate the existence of the ionosphere would require finding evidence that radio signals arrived over at least two paths, a ground wave and a sky wave. To take an example: If one were to set up a receiver thirteen miles from a radio transmitter, and if the ionosphere layer were 100 miles above the receiver, two pulses should arrive — first a direct pulse and then, a millisecond later, a reflected pulse. If the height of the ionized or reflecting layer were increased or decreased, then the difference in time of arrival of the two pulses would change correspondingly. Tuve devised the necessary detecting equipment, and Breit and Tuve were able to use a Naval Research Laboratory oscillator for their source of radiation. They observed delayed pulses but could not be sure that they were not reflections from the Blue Ridge Mountains. However, one evening they found that after sunset the reflecting layer moved upward from a height of about sixty miles to above 115 miles as the delayed pulses began to arrive at longer intervals. The experiment was a success. Breit persuaded Johns Hopkins to accept the work as the basis for Tuve's Ph.D. thesis, and the degree was granted in 1926. Verification of the existence of the ionosphere opened an important field of research and suggested the practicability of radar.

Throughout his life, Merle displayed excellent critical judgment in identifying the most significant challenges and opportunities of the times. In 1926 he recognized the great importance of exploration of the atomic nucleus. To implement his vision, he planned to go to England to Rutherford's laboratory. However, Breit and John Fleming, who was then Acting Director of the Department of Terrestrial Magnetism, talked him into coming there, where he was to be given an opportunity to develop equipment for production of energetic particles.

Several years of difficult and frustrating work followed, in which Tuve achieved high voltages using Tesla coils and even acceleration of protons to relatively high energies. But the equipment was plagued with failures of glass insulators. However, Tuve learned the hard way how to distribute voltage along a column. When Van de Graaff invented his belt charging high voltage generator, Tuve was in position to adapt it as an excellent tool for experimental nuclear physics. Starting in 1932, the laboratory was one of the leading centers of nuclear physics. Leading theoretical physicists were frequent visitors. Breit moved to New York University in 1932, but he remained a steadfast friend and consultant. A high point in scholarly exchange came in January 1939, when Niels Bohr told a conference of theoretical physicists of the discovery of uranium fission by Hahn and Meitner. Within a day the discovery was confirmed at the Department of Terrestrial Magnetism.

But the high mark in achievement came in 1935 with a series of experiments by Tuve, Hafstad, and Heydenburg on proton-proton interactions. It had been long known that like charges repel each other. Yet atomic nuclei exist containing 92 protons and more. What holds such nuclei together? Through precise measurements with high energy protons from their Van de Graaff accelerator striking a hydrogen gas target, the experimenters were able to answer the question. At intermediate and long distances, protons repel each other. But at short distances, that is, of the order of 10^{-13} cm, an attractive force exceeds the repulsive one. Analysis of these data by Breit yielded a nuclear potential that was identical to that of the neutron-proton interaction, which had been obtained by Goldhaber by photo-disintegration of the deuteron. This discovery was immediately recognized as an historically significant milestone in nuclear physics.

Tuve focused his effort on nuclear physics until 1940. He supervised the designing of a pressurized Van de Graaff generator. This generator achieved energies above four million electron volts. He also began construction of a sixty-inch cyclotron designed to produce large quantities of radioactive isotopes for use on the east coast.

However, events across the ocean impinged heavily on him in 1940. One Sunday afternoon I was working in a laboratory at the Department when Tuve came in. He had been listening to accounts on the radio of destruction caused by a massive Luftwaffe raid on England. He spoke intensely of the need for defensive measures. I was working on a method for isotope separation and did not join the sudden flurry of activity that followed during the next week. From his experience with radios and electronics, Tuve could visualize that an electronically actuated proximity fuze might be feasible which would enormously increase the effectiveness of ground-based antiaircraft fire. But such a device would require rugged vacuum tubes that could withstand the forces encountered when it was fired from an artillery piece. This crucial problem was immediately tackled by the simple expe-

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dient of dropping lead-encased tubes from the top of a building to a concrete apron below. This crude method in turn was quickly supplanted by tests with known forces in centrifuges. Once rugged tubes were available, the design and production of prototype devices was accomplished. These were tested by Tuve's group and ultimately by the Navy. In 1942, the Navy gave the go-ahead for large-scale production. Tuve understood the importance of quality control and of guaranteeing against accidental misfiring that might injure naval personnel. Misfiring was guarded against by a superior design. Quality control required careful monitoring by a large staff. This in turn required a transfer of activities from the Department of Terrestrial Magnetism to larger quarters in a newly formed Applied Physics Laboratory administered by The Johns Hopkins University and directed by Tuve. This also took place in 1942. During the next three years millions of proximity fuzes were manufactured. Many variants of the original design were devised and produced. In terms of effect on the course of World War II, the proximity fuze was one of two or three of the most important new military devices.

After the war, Tuve received the Medal for Merit from President Truman and was named an Honorary Commander in the Order of the British Empire. He also received the John Scott Award of the City of Philadelphia. On that occasion, Tuve revealed what must be regarded as an essential component of his success in the proximity fuze effort. He stated that the principal discovery of World War II was the efficiency of the democratic principle in dealing with people. He said:

> The democratic principle is this: Tell the worker or the people of the community what the need is, invite them to contribute in the best way they can, and let them help you and help each other meet that need. Any society or any group always selects men to handle certain tasks, by elections or by hiring them or by some other system. But notice that a boss using the democratic principle does not depend on orders, he asks his men, his workers, to participate. This means that they help him with the whole job, they don't just do what they are told to do. This system of asking people to help with the whole job was what I used in running the proximity fuze development. It worked so well, the whole team took hold so vigorously, that during most of the work it was a struggle to keep up with them. I often felt like a short-legged donkey trying to keep from being run down by a stampede of race horses.

It is obvious that Tuve was an excellent administrator capable of directing large enterprises. After the end of World War II he might have chosen any one of many major managerial careers. But Tuve was a man of ideals and ideas who put research and discovery ahead of power and position. He left the Applied Physics Laboratory, where he had dominion over thousands of people, to become Director of the Department of Terrestrial Magnetism, where the professional staff numbered about fifteen and where austerity was a way of life.

Vannevar Bush, President of the Carnegie Institution of Washington, had established the policy that the Institution would not expand its activities in peacetime research by taking government funds. Tuve wholeheartedly agreed with this policy. But a consequence was that he deliberately foreclosed the option of spearheading activities in big science, including the development of the next generation of large accelerators for high energy physics. Instead, he preferred to seek areas of inquiry in which tiny groups of research scientists might make significant contributions. To implement this vision, it was necessary to change the thrust of the Department of Terrestrial Magnetism. Prior to 1946, the organization had for the most part conducted activities consonant with its name. Tuve changed that. He converted it into a physics department and further stated that physics is what physicists do. Thus staff members, who in the main were physicists, had a broad license to use their imaginations in defining significant areas for research. This freedom led to very productive ventures by some of the staff, including those in molecular biology and in the radioactive dating of rocks. During the period 1946-1966, while Tuve was Director, he carried out administrative functions and responded to numerous calls for public service. However, personal involvement in research was his principal activity. His fields of investigation included experiments in seismology, radio astronomy, and the development of superior optical image tubes.

Tuve's first personal research following his return to the Department of Terrestrial Magnetism in 1946 had as its goal discovery of knowledge about the interior of the earth. At that time, geophysicists were dependent on observations of earthquakes for information about the lower crust and mantle. But earthquakes are undependable with respect to both time and place, and observations lead to only approximate descriptions of the earth's interior. In 1946 geophysicists hypothesized that the structure of the earth was somewhat analogous to that of an onion, with an outer layer of granite overlying a basaltic layer, which in turn was above other concentric structures. Tuve and associates, including Howard Tatel, ultimately showed that the earlier model was oversimplified.

To facilitate obtaining detailed knowledge of the crust and mantle required a more dependable probe than earthquakes. Tuve chose to use explosions to produce vibrations in the earth, and he and his group developed new sensitive seismometers that could detect the tremors at distances of hundreds of kilometers. Up to the time of the Korean War he was able to persuade his friends in the Navy to provide explosives and detonate them for him. Later he used large explosions being conducted in quarries as a source of seismic waves. Altogether, hundreds of experiments were done and the data analyzed. Many of the observations were made in various regions of the United States, but a substantial effort was devoted to South America and especially to the Andes.

Part of Tuve's personal attention to seismology was diverted in 1952. At that time, Ewen and Purcell at Harvard had discovered radio emission from neutral hydrogen in our galaxy. Tuve went to Cambridge and obtained from them parts of the receiver that they had used for their discovery. A 23-foot diameter German radar dish, borrowed from the National Bureau of Standards, was installed at the Department of Terrestrial Magnetism. Characteristically, Tuve set about improving the essential auxiliary electronic equipment and soon had what at the time was the best of its kind in the United States. From 1953 to 1965, the Department of Terrestrial Magnetism was a leading center of radio astronomy. Ultimately others, using federal funds, were able to obtain superior equipment, but in its day the small group at the Department of Terrestrial Magnetism was among the world leaders.

Tuve's venture into the development of image tubes was not so much a personal research effort as an exercise in guiding the production of an important tool for astronomy. Through his superb grasp of electronics he was able to visualize that a major increase in the effectiveness of telescopes was attainable. Photographic plates have been rendered very sensitive, but still they convert only a fraction of the incident photons into an image. Photoelectron emitters are more sensitive, and the electrons can be accelerated and their number greatly amplified. Under Tuve's chairmanship, a committee designed a tube that improved the detection of light from distant stars. The end effect was equivalent to what might have been obtained if the diameters of telescopes had been tripled.

One of Tuve's strengths was his ability to select and attract very high quality associates and staff members. Throughout his career, most of his projects were accomplished with the cooperation of one or two close associates. Tuve served as the major source of fresh ideas, enthusiasm, and drive. Often there were more ideas than might be implemented, and the gifted associates provided discrimination and sounding boards, resulting in an enhancement of Tuve's own excellent native judgment. The careers of scientists who experienced some years of contact with Merle were fostered, and many have expressed gratitude for the association.

Tuve's willingness to respond to calls for public service has already been mentioned. He participated in many such activities. He served on the first U.S. National Commission for UNESCO, on the National Research Council's Committee on Growth, and on the U.S. Committee for the International Geophysical Year. He was the first Chairman of the Geophysical Research Board of the National Academy of Sciences and Home Secretary of the National Academy of Sciences.

In addition to the awards already mentioned, he received the American Geophysical Union's Bowie Medal for unselfish cooperation in research; the National Academy's Barnard Medal for meritorious service to science; the 1948 Comstock Prize of the National Academy of Sciences, given every five years for the most important discovery or investigation in electricity, magnetism, or radiant energy; the Bolivian order of the Condor de los Andes for efforts in advancing science in South America; and the Cosmos Club Award. In 1943, he was elected a member of the American Philosophical Society. He was also the recipient of seven honorary degrees. He found great satisfaction in a ceremony at Carleton College, presided over by Lawrence Gould, who was then president of the college. On that occasion honorary degrees were conferred on Merle, on his two brothers, George Lewis and Richard Larsen, and on his sister, Rosemond. All had achieved distinction in their professions.

Merle was married in 1927 to Dr. Winifred Gray Whitman, and in keeping with his regard and respect for his mother and sister and his strong feeling about equal rights for women, he insisted that Dr. Whitman continue her professional work under her maiden name. Merle and Winifred had two children, Trygve, who died in 1972, and Lucy, who survives. Both earned Ph.D. degrees and both pursued scientific careers.

A former President of the American Geophysical Union, George Woollard, characterized Merle Tuve in words with which all who knew him would agree:

> Anyone who knows Merle Tuve recognizes that he is a driver, who has never spared himself; a crusader, who has espoused the cause of science to the government and the people of this country; a patriot, who never questioned the wisdom of devoting some of his most productive years to classified military research; a leader, who had much to do with the success of the International Geophysical Year as well as with the outstanding reputation enjoyed by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington; a public servant, who has devoted much of his time to the service of his fellow scientists through service on various boards and committees of the National Academy of Sciences and other groups; a diplomat, who has done much to foster both understanding and working relations between American and foreign scientists; and, finally, a warmhearted individual, who has always been willing to help others.