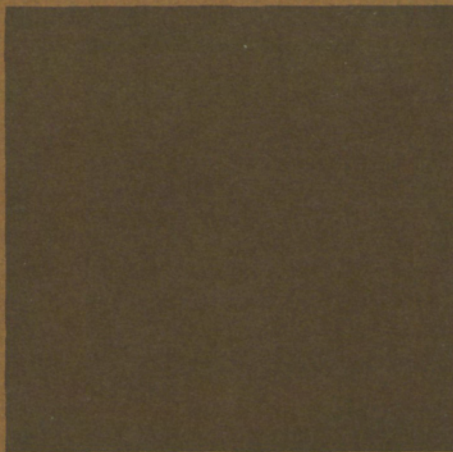
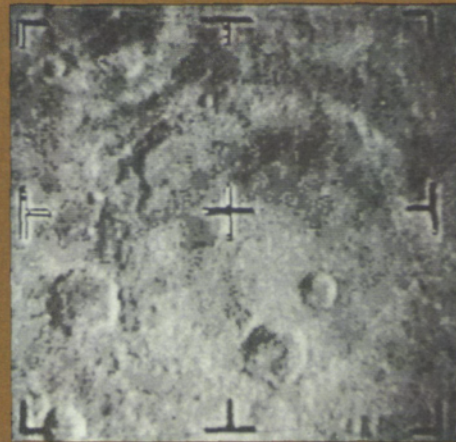


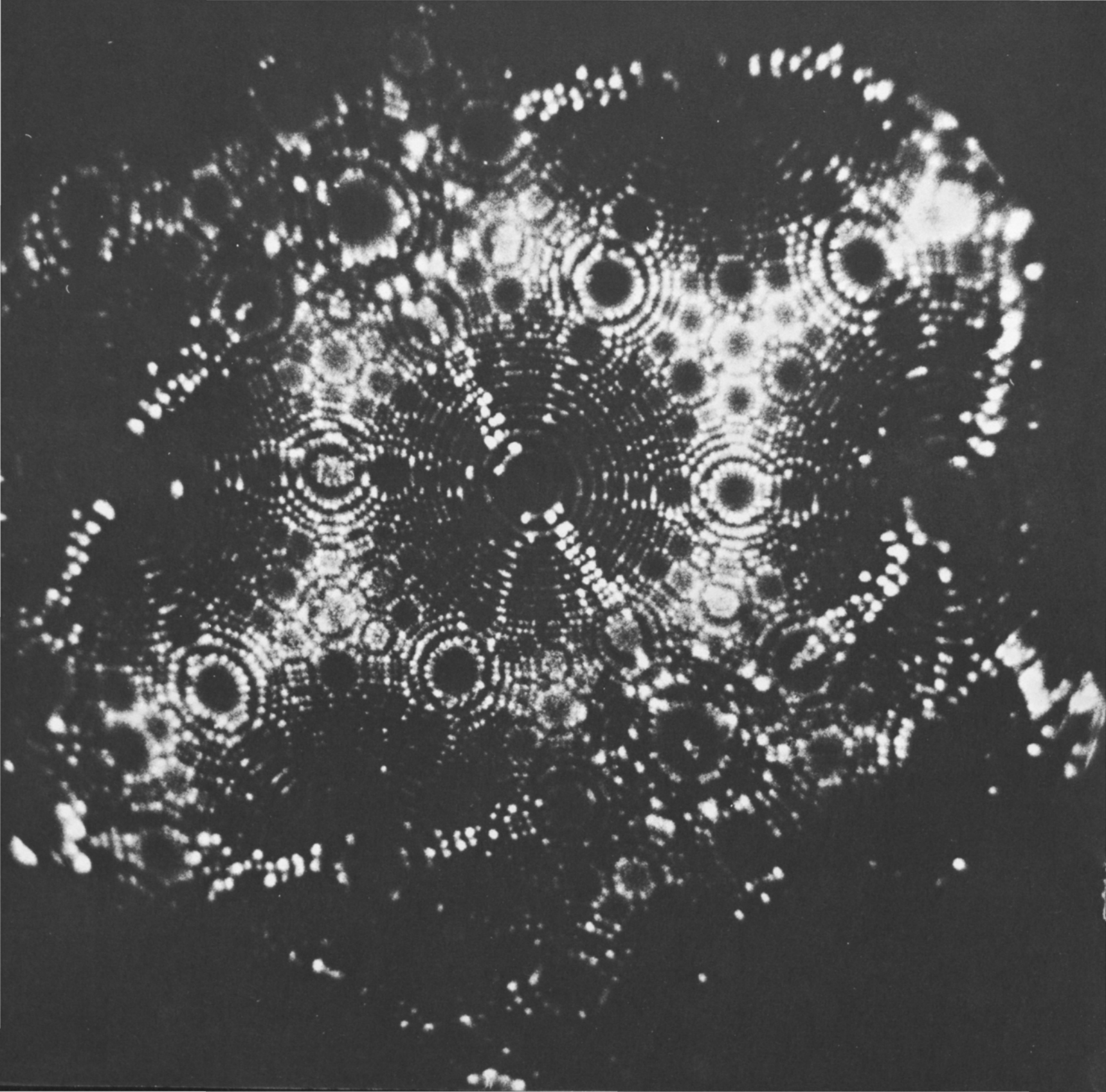
ENGINEERING

CORNELL QUARTERLY



VOLUME I
FALL 1966

A LOOK
INTO THE
FUTURE



IN THIS ISSUE

A Look Into the Future /2

What is the future of scientific research in industry? What lies ahead for engineering research and development? What should be the characteristics of an engineering education designed to meet future needs? To what extent will interaction occur between industrial, educational, and government laboratories? Frank E. Marble of the California Institute of Technology, General Electric's Arthur M. Bueche, Kenneth L. Bowles of the University of California at La Jolla, and Avco's Arthur R. Kantrowitz examine the future of scientific research in industry, engineering research and development, engineering education, and cooperation between industry, education, and government. Discussion of these topics was the concluding feature of the Twentieth Anniversary Program, a two-day conference held at Cornell on June 16-17, 1966, honoring the twentieth anniversary of the Graduate School of Aerospace Engineering and the Department of Engineering Physics.

The Next Twenty Years in Aeronautics and Space /26

Beginning with air travel to various points on earth, and then turning his attention to interplanetary travel (using Mars as a destination), Mac C. Adams, deputy director of the National Aeronautics and Space Administration, highlights some of the areas that will demand the attention of tomorrow's aerospace "pioneers."

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This month's Register honors the recently appointed Spencer T. Olin Professor of Engineering at Cornell, Trevor R. Cuykendall, who has been a major force in the establishment and continuation of the engineering physics program; and also features Professors Mark S. Nelkin and Everett M. Strong.

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Two Decades /39

Cornell's highly successful aerospace engineering and engineering physics programs represent an effective combination of students and faculty working at the junction of engineering and science. ENGINEERING: Cornell Quarterly editor, Donald F. Berth, reviews the results of the first two decades of these programs.

ENGINEERING: Cornell Quarterly, Fall, 1966, Vol. 1, No. 3. Published four times a year in April, July, October, and January, by the College of Engineering, Cornell University, Carpenter Hall, Campus Road, Ithaca, New York 14850. Second Class postage paid at Ithaca, New York. Subscription rate: \$2.50 per year. © 1966 by the College of Engineering of Cornell University.

Opposite: Stereographic projection of a hemispheric cap of high purity tungsten wire (magnified ten million times) obtained with a field ion microscope.



A LOOK INTO THE FUTURE

■ What is the future of scientific research in industry? Will it be applied or basic? What kind of people will be required?

■ What lies in the future for engineering research and development, and how is this related to engineering education?

■ What should be the major characteristics of an engineering education to meet the needs of the 1980's?

■ What will be the degree of interaction between industrial, educational, and governmental laboratories in the future?

It was to these questions that a distinguished panel addressed itself this past June as part of the Twentieth Anniversary Celebration of Cornell's Department of Engineering Physics and Graduate School of Aerospace Engineering. Each of the four participants—industrialists Arthur M. Bueche and Arthur R. Kantrowitz, and educators Kenneth L. Bowles and Frank E. Marble—considered one set of the questions, and attempted to forecast how the needs of tomorrow will affect the direc-

tion of engineering education.

Forecasting future scientific developments and needs may be hazardous and fanciful at best. Yet only through such extrapolation can education prepare itself to lead in new ventures. The hallmark of the faculty of both Engineering Physics and Aerospace Engineering has been their ability to anticipate the future, and in their short history of twenty years, both divisions have made a substantial contribution to modern engineering practice and education.

These four panelists—Bueche, Kantrowitz, Bowles, and Marble—all have had a Cornell affiliation. Kantrowitz was one of the early professors in the Graduate School of Aerospace Engineering, and Marble was a Visiting Professor in the School in 1955. Bueche has a Ph.D. degree in physical chemistry from Cornell, and Bowles was a member of Cornell's first graduating class in engineering physics.

Today, Kantrowitz is vice president of Avco Manufacturing Company and director of their Everett Research Laboratories. He received a Ph.D. degree in physics from Columbia, and has

been a Fulbright scholar at Cambridge and Manchester, a Guggenheim Fellow, and a Visiting Lecturer at Harvard and M.I.T. He and his brother Adrian, a surgeon, are noted for their work on the development of artificial heart valves.

Marble is Professor of Jet Propulsion and Mechanical Engineering at Caltech, where he earned his Ph.D. degree in aeronautics. He has consulted for the U.S. Departments of the Air Force and the Navy, and was recently elected a Fellow of the American Institute of Aeronautics and Astronautics.

One of Bueche's major responsibilities as vice president in charge of the General Electric Research and Development Center is to shorten the time lag between basic scientific discoveries and the application of these discoveries to new and improved products and services. As a major contributor to polymer science and technology, Bueche was associated with chemical research activities at G.E. until 1965, when he assumed leadership of the Research and Development Center and its staff of more than 1800. He is chairman of the board of trustees of the

Gordon Research Conferences and was recently named to Cornell's Engineering College Council.

After graduating in the first class in engineering physics in 1951, Bowles received his Master's and Ph.D. degrees at Cornell in electrical engineering. He has received the Gold Medal of the United States Department of Commerce for his "outstanding contributions to radio science." Formerly with the National Bureau of Standards at Boulder, Colorado, Bowles is now Professor of Applied Electrophysics at the University of California at La Jolla.

To found the engineering physics and aerospace programs, the faculty had to break down the traditional barriers that divided the problems of science and engineering into isolated Departments of Physics, Mathematics, and Chemistry, and Schools of Electrical, Mechanical, Civil, and Chemical Engineering. Today, it is equally important that other barriers be overcome, particularly those which frequently block effective communication among industrialists, researchers, and educators. Such is the purpose of "A Look into the Future."



MARBLE: A LOOK INTO THE FUTURE

Interaction among Industrial, Government, and Educational Laboratories in the 1980's

The general pattern of engineering education over the past ten years shows an increase in scientific and mathematical content, and so, I believe, will the next twenty years. There are good reasons for this. One of the firmest reasons is that we have to know things more accurately now than we did earlier. We know that accuracy requirements for constructing road beds, for example, are certainly less stringent than those required to make an airplane work. And the difference between success and failure in one of today's space shots is extremely narrow. Consequently we have to compute more accurately and base our calculations on more substantial ground than ever before.

Now this does not change the aims of engineering. Engineering has always had an "objective" motivation: to make something that works! This aiming of activity at a particular goal is (or I think it should be) true not only in engineering practice, but in engineering research as well.

Another powerful influence on engineering programs is the realization that engineers change fields often. In the

aerospace industry, for example, an engineer can expect to work, at most, about five years in any one field. Roughly every five years, he will have to start learning new things. Of course, there is a continual educational redevelopment going on in any productive engineer and the organization he works for. But engineering problems come and go at such a rapid rate that no one who leaves school today can count on getting a position that utilizes the specific knowledge he may have obtained. Furthermore, he cannot reasonably expect to maintain competence in a particular field for more than five years. While this is not necessarily true of some of the less dynamic fields, the recent twenty-year pattern suggests that education needs to develop engineers who can change fields easily. Educational requirements for the next twenty years must emphasize these two points.

Engineering now covers a broad spectrum, all the way from "nuts and bolts" engineering to the most esoteric of engineering research activities. Consequently, motivation and objectivity are difficult to sustain. This is true for



Above: Frank E. Marble

Opposite page: The laboratory program in engineering physics is noted for its variety and for the emphasis it places on individual experimentation. Students are shown here:

- 1. Studying the characteristics of active circuits.*
- 2. Calibrating electronic components for an undergraduate electronics laboratory.*
- 3. Examining the spectrographic analysis of atomic spectra.*

*...flexibility is bound
to be the 'key' in
training engineers...*

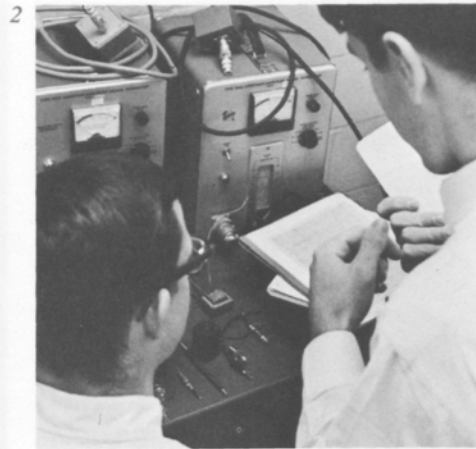
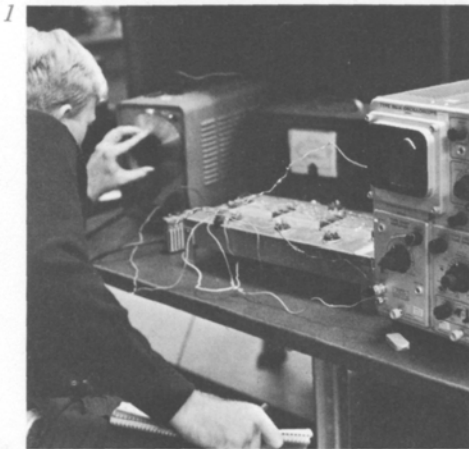
...the theory of computing actual engineering tasks such as those required of calculating time of an airplane in passing through a rain. Each of these experiments involves many things which are of importance in applied engineering activities. If you will, I believe you have had this experience in many of our engineering courses.

Since I am not engaged in applied research work, it is probably just as well that I stress the value of experimental work. As the scientific and mathematical aspects of engineering become more and more important, it is necessary to

education and for industry. It is even harder to maintain objectivity in industry, partly because of industry's tendency to separate its engineering talent into various levels. The research lab thinks itself a little bit better than the next level down; and so on down, from level to level!

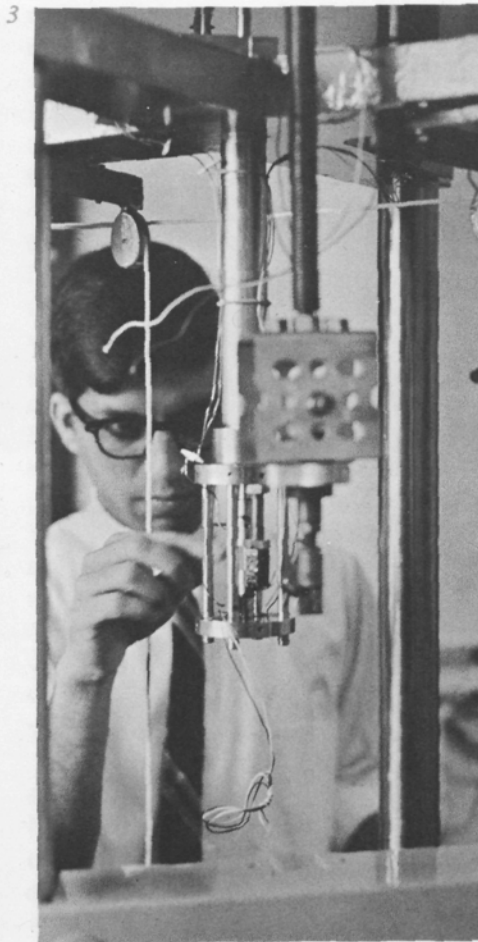
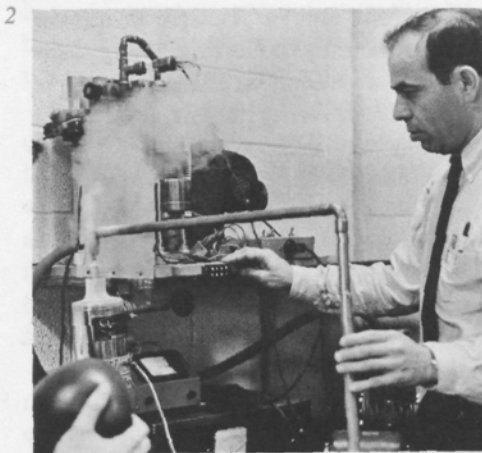
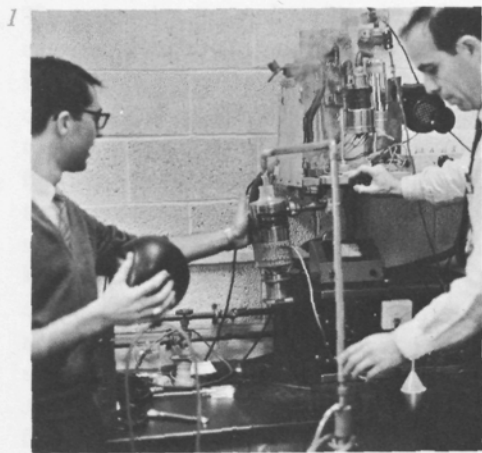
Perhaps of greatest concern to me is the fact that engineering has lost much of its creativity. This comes up frequently when students talk about the contrast between engineering and science. They can recognize the creative process in mathematics, a process where you "find" a principle or a theorem, which by collecting many facts can explain a thing in terms of a simple statement; it's easy to put your finger on creativity in science, too, for here again one can discover a fundamental principle not previously known which may have been derived by individual or group experimentation. In brief, creativity in science or mathematics stems from a more unitary base than it does in engineering.

It's a little bit harder to define creativity in engineering, and this is one of



MARBLE: A LOOK INTO THE FUTURE

Interaction among Industrial, Government, and Educational Laboratories in the 1960's



Left: Photographs 1 and 2 show Boris W. Batterman, Associate Professor of Materials Science and Engineering, at work with a graduate student in x-ray diffraction research. Liquid helium is being transferred into a Dewar to study crystal structure at 4° K.

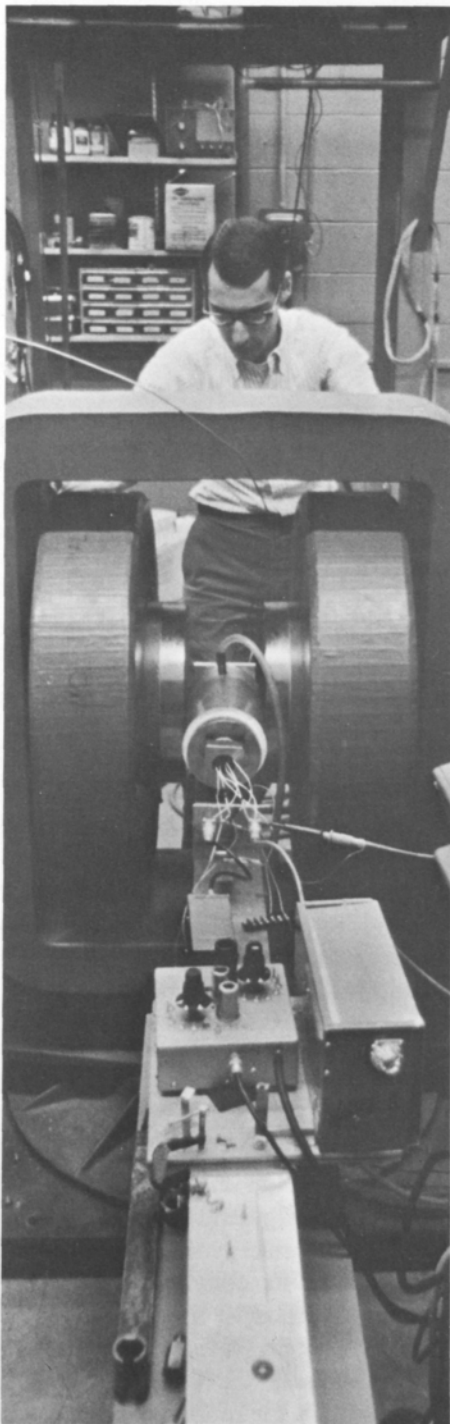
3. Another student is studying the relationship of point defects to fatigue.

Opposite page: Adjusting magnets to study the pressure dependence of self-diffusion in aluminum using magnetic resonance techniques.

our major educational chores facing us. It must be recognized that the engineer may be found working on several different levels, each requiring a different "brand" of creativity.

To discern how creativity can come about in engineering, one may find an analogy within the biological sciences. Here one recognizes different strata of complexity. One does not try to explain complicated animals in terms of very complicated things. Rather, complicated organisms are explained in terms of the less complex.

Now, being creative may well mean jumping from the kinetic theory of molecular structure to the equations of continuous media, or from the equations of continuous media to a theory of a boundary layer. However, it is something else to go from boundary



layer theory to computing actual engineering facts such as those required in calculating drag of an airplane or pressure drop in a pipe. Each of these applications correlates many things which are of importance in applied engineering: creativity, if you will. I believe we have lost this transference in many of our engineering courses.

Since I am not engaged in experimental work, it is probably just as well that I stress the value of experimentation. As the scientific and mathematical aspects of engineering became more common as well as dominant, it became much easier to teach with a theoretical orientation and to supervise research work that was theoretical in character. It was just a lot of work to either teach the experimental or to supervise research in the experimental area. The consequence of this dichotomy is the unfortunate swing toward analytical work.

I can illustrate this problem by relating one particular example. A young faculty member was sought by an aeronautical engineering department. They interviewed forty men. Of these, five were experimentalists, and of these five only two had any kind of qualification as experimentalists. We shall have to see what can be done to cure this ailment in the next several years.

Industry must also maintain objectivity. Every now and then industrial research people need to be told, "Look, it seems to have slipped your mind, fellows, that we're trying to make money here. We need to make products in order to make money. Now let's get our research a little bit more product-oriented and have something coming out of here." There is, then, a reason-

"...flexibility is bound to be the 'key' in training engineers..."

able middle ground here, which some aerospace companies have not yet found.

Since flexibility is bound to be the "key" in training engineers and in their professional lives, I feel that government and industry must equip their employees to make simple and productive field changes. Change needs to be recognized as an industrial habit. Greater efforts are going to be required in organizing activities which will enhance one's capacity to change from one specialty to another.

Let me just sum up what I think are the important points to watch for in the future training of engineers. One is the maintenance of objectivity, or motivation. Second is the recognition by faculty of the creative aspect: to realize that there is a creative step, to emphasize it, to recognize it when it happens. The third is to emphasize the importance of experimental work. And, finally, engineering education must realize that its main task is to provide engineers with a standard of excellence that can be maintained throughout the whole of their professional lives.

BUECHE: A LOOK INTO THE FUTURE

The Future of Scientific Research in Industry

What kinds of people will be required for the future needs of scientific research in industry? You've probably heard the definition: "If I want to do it, it's basic research; if you want me to do it, it's applied research." To this a friend of mine has added: "If it costs twice as much as we thought it would, it's development; if it really works, it's engineering; and if it makes a profit, that's either professional management or good accounting practice."

The kind of industrial research I'd like to discuss—when I'm not talking about research and development—might be defined as exploring for fundamental new knowledge, performed by highly talented and innately curious people who also have some knowledge about and interest in the objectives of the sponsor. And I think there is going to be a lot more of this kind of research.

How much of it is there now? In general we can say: United States research and development now costs something over \$20 billion a year. One-third of this is typically defined as "R," two-thirds as "D." Only about one-third

of the "R" comes under the heading of "basic R."

Now for industry's part of this: Industry performs nearly three-fourths of the total R&D, one-half of the "R" and one-fourth of the "basic R." In all three areas industry provides about one-half of the money itself, and gets the remainder from the federal government. Thus, in round numbers, American industry spends—of its own money—some \$7 billion every year on R&D, of which a little over \$2 billion goes to research, including some \$500 million for basic research.

Now what about the future of research in industry? Recently I have become responsible for helping to ascertain the future patterns of research and development in a particular company, and my comments may be flavored with some of the considerations of a specific situation; however, because of the diversity of the company in question I won't hesitate to generalize on the basis of some of our planning.

First of all, of course, it is widely recognized that although national R&D, including the industrial portion, will

continue to grow, the rate of growth must necessarily decline from the phenomenal pattern of recent years. You are all familiar with that extrapolation of current rates which shows clearly that R&D expenditures will surpass the Gross National Product at some early future date. With the total R&D package, however, I believe the percentage of "R" will increase. This is certainly true for industrial research, since it is now becoming clear that the future growth of many industries will depend on things not yet known and inventions not yet made.

Industrial companies must take a broad and imaginative look at the truly big and exciting challenges of the future: the new age of cities, getting into the business of completely planned communities, contributing to overall control of our environment, new sources of energy and ways to distribute it, the information-handling revolution with all its connotations, a new look at education as a continuous and life-long process, a first look at the fundamentals of the learning process, transportation for more people and for

different reasons, meeting the needs and wants of people with lots of leisure time, space exploration, and whole new kinds of man-made materials that will revolutionize our ways of manufacturing most things.

Fundamental knowledge of nature from which engineers can fashion some elements of this new world now exists; but the major achievements (and the excitement and the fun) will come from totally new opportunities based on new knowledge uncovered by research. Industry will do more, not less, of this kind of work.

At the same time, I think the people in industry who are performing research will know more and more about the plans, projects, products, problems, and aspirations of the sponsor of their work. And I do not think this will in any way pollute the "purity" of discoveries that are made or lessen the thrill and excitement of making them. The day of the "introvert" scientist who can ignore his social environment has long since passed. Many scientists in industry will find themselves participating for the first time

on business-planning and development teams, working much more closely with engineers and also with manufacturing, marketing, and finance people.

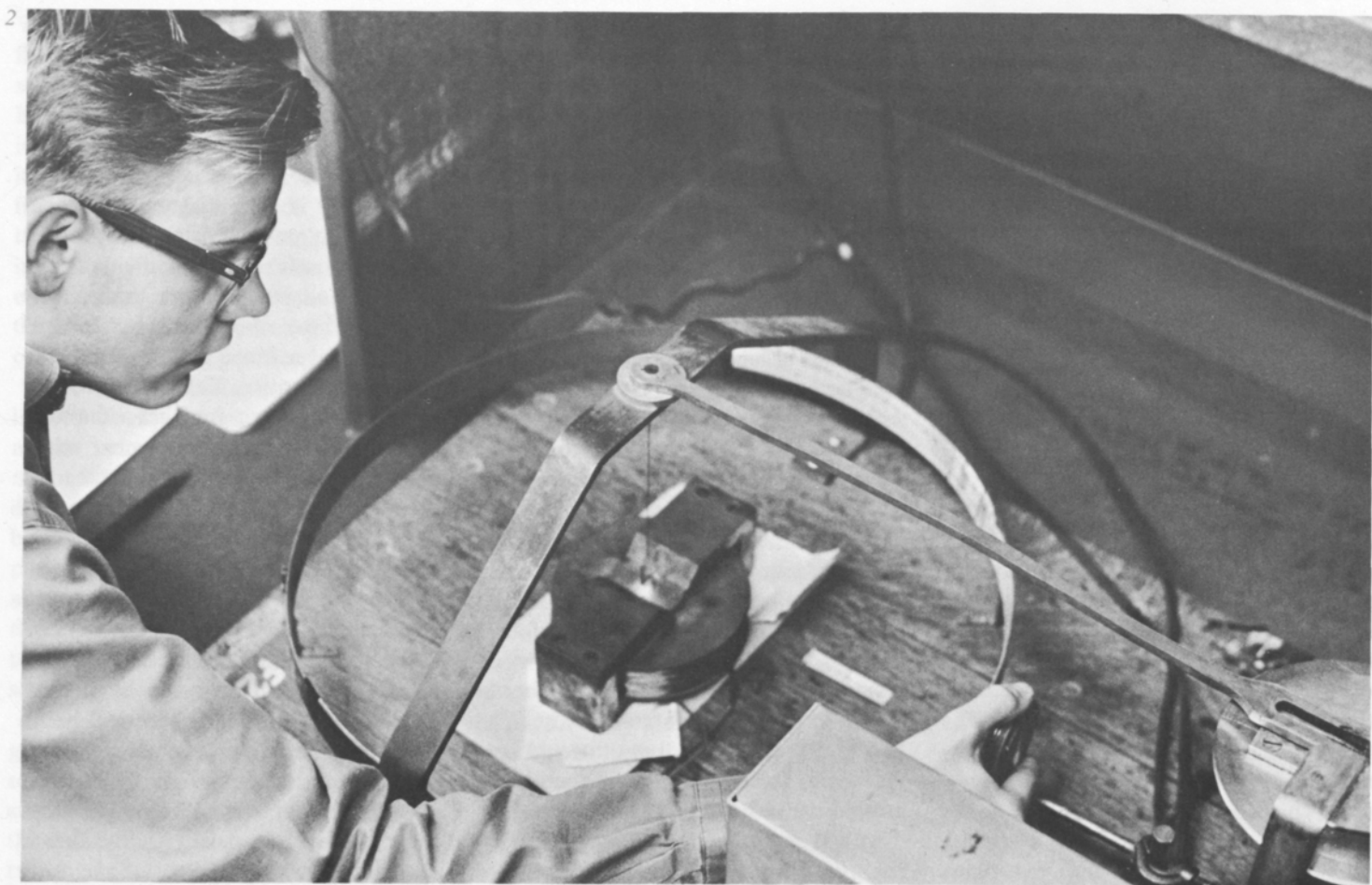
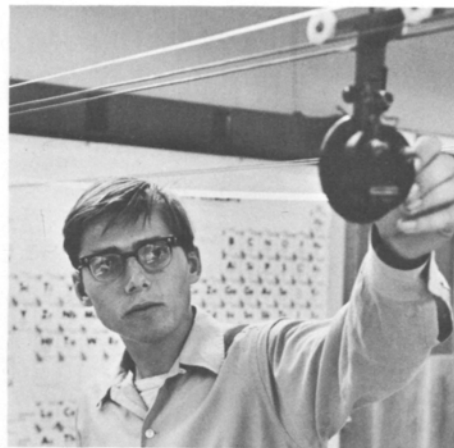
The leadership of American industry has been finding itself reflecting the growing importance of the R&D function. This will continue and grow. Certainly, tomorrow's general manager will have to be concerned intimately with R&D, with the choice of programs, with the urgency for shortening the time between discovery and profit, and with the need to remove organizational and other artificial barriers to R&D effectiveness. More and more industrial concerns will find more and more of their top management people coming from the technical ranks.

Also, in the future of industrial R&D, I foresee arrangements whereby industrial scientists and engineers will find themselves, in ever increasing numbers, working at major centers of research and development activity throughout the world. I need do no more than look around me to be quickly reminded that there are major centers of learning and expertise (such as Cornell University)

from which technical people working in industry can learn a great deal. I would suggest that many industrial people could contribute, as well as learn, by working more closely with such centers.

The scope and variety of scientific opportunity is now so great that technical people are increasingly dependent upon one another. No individual can hope to understand more than a tiny segment of the whole; no single laboratory can cover more than a small fraction of the frontier. Thus, we need new ideas for working together—the university scientist, the government scientist, and the industrial scientist, the scientists here in the United States with the scientists abroad. We must therefore seek ways for industrial and university laboratories to interact more closely with the important governmental laboratories. But the creative discoveries will still be made by people, single individuals, and there will be no substitute for this manner of discovery in the foreseeable future or for the organization of research and development activities in a way that makes it easy for good people to talk to each

BUECHE: A LOOK INTO THE FUTURE
The Future of Scientific Research in Industry



1. *A senior laboratory—determining the resonance of a radio frequency transmission line.*
2. *Here, a student measures the magnetic susceptibility of weak magnetic crystals.*
3. *Engineering physics and physics students use one corner of the senior laboratory to work out their laboratory calculations.*

other and then to think and act independently. We must never lose sight of this important fact.

What about the scientists and engineers yet to be educated? What should they be like? Although I am generally optimistic about the ability of scientific and engineering education to meet the challenge posed by the explosive expansion of technology, the problems are not trivial, and, in the current excitement, some confusion is evident. For some reason there seems to be greater general satisfaction with the education of scientists than with the education of engineers. At least there is more concern with and discussion of engineering education. One result of the apparent relative success of curricula for the training of scientists has been a tendency to copy these techniques in the training of engineers, and this may be a source of the problem. Scientists and engineers must work very closely together (frequently side-by-side) but there is no justification at all for considering their's to be other than quite separate and distinct professions, requiring their own kinds of educational preparation.



*“What is required,
at least by industry,
is an increasing
number of ‘doctor
engineers’ who have
had the benefit of
truly advanced work
in engineering...”*

Arthur M. Bueche



Let me conclude with some comments on engineering education as viewed by some people in industry. Some of the things I will have to say in this regard rather directly reflect the conclusions of two of my associates in General Electric who have been studying the problem for many years, Frank McCune and Guy Suits.

Mr. McCune, who has given careful thought to this matter, describes the appropriate role of the engineer in industry in this way: “The work of the engineer is balancing available inputs to synthesize and to optimize, so that his end product—which is a design—will enable the organization he serves to produce a competitive value at a competitive cost. By ‘design’ is meant here a concept of a product or an entity which uses the abilities of the business enterprise to produce something that meets customer requirements, and which is worth more than it costs to produce.”

Industrial research, then, is exploring for new knowledge about nature that may be useful to the sponsor. Industrial engineering is the producing of designs based on scientific knowledge of nature plus existing engineering technology plus “non-engineering technology” (knowledge of customers, business systems, manufacturing capabilities, economic environment, and so on) to make a profitable link between industrial resources and customer requirements.

A reasonable pattern for producing this kind of engineer does seem to be evolving. Many industrial observers conceive this to include: four years of rather liberal education in science, humanities, and mathematics leading

to a bachelor's degree; then one or two years of education in creative design engineering, at the graduate level. Expansion of education in engineering at the doctoral level is urgently needed, but with a caution that needs emphasis: the motivation should not be the "winning of a doctoral race" with scientists, nor the achievement of status symbols. What is required, at least by industry, is an increasing number of "doctor engineers" who have had the benefit of truly advanced work in engineering, rather than research-type Ph.D. training in a scientific discipline.

There is a continuing good case to be made for the viewpoint that graduate study for engineering careers in industry should be concurrent with (and intertwined with) actual employment. The mix of information and practical proficiency—how much of each—that is most appropriate for different fields of engineering varies widely. There are many advantages to seeking a proper balance in an actual job situation. On-the-job engineering situations can provide excellent motivation for education beyond the bachelor degree, and are helpful in determining the directions that such continuing education should take.

The extension, seemingly *ad infinitum*, of what the educated engineer must be educated *in* is, of course, not just a result of the belief that he must know more about his scientific resources. There is also the matter of sheer massiveness of engineering technology, plus the need for a more-than-complete liberal arts background encompassing economics, business administration, political science, psychology, philosophy, and even, it is to

be hoped, learning how to express what he thinks. In this context I can't resist quoting a little four-line verse that one of my associates has called "The Dean of Engineering's Lament:"

Our new curriculum will surely
create
The greatest engineer alive,
But the day before he's to graduate
He'll retire at sixty-five.

One obvious (too obvious and not very satisfactory) answer to this quandary is specialization, the completely specialized engineer. But it seems to me that among the great problems of modern education is keeping the student engineer—or student scientist—from becoming too specialized, especially in the wrong things. As a practicing specialist in industry later, the graduate has the problem of retaining enough flexibility to permit response to the ever-changing needs of modern technical employment. The technical community—which has done so much to initiate change—should be the last to meet it unprepared.

The company I represent spends some \$600 million dollars a year on research and development. The figure is a staggering one, but represents only about two percent of the world's R&D. We are not looking for people who think they learned it all in college. More especially we are not looking for people who think they can keep up with their profession merely by keeping up with new ideas from those with whom they work. We must have people willing and anxious to learn—from *all* the world around them—and prepared to continue this learning every day of their lives.

I should assure you that industry does not presume that it can ask all this without offering something in return. Industry must and will continue its general support of higher education in the United States, including scientific and engineering education. We do this recognizing that the colleges and universities are our most critical resource, and that their continuing strengths and effectiveness are vital components of industrial progress.

BOWLES: A LOOK INTO THE FUTURE

Needs of Engineering Education for the 1980's

As an alumnus of Cornell's first engineering physics class, who ranked nearer the bottom than the top of the graduating class, it would have seemed incongruous had I then been told that I would ultimately be called upon to make the contribution of this article on the 20th anniversary of engineering physics at Cornell. However, as an educator now involved in planning a new science and engineering program at the University of California at La Jolla, the thoughts that I should like to share with you are quite naturally those of one who is very closely associated with an applied physics program.

Cornell's engineering physics program was conceived and developed as an elite program which would combine the good points of both engineering and physics in an optimum way. I'd like to interpret its objective as an effort to filter out students with potential for leadership, and then to launch them in that direction in applied physics. The scuttlebutt passed among a number of those early graduates indicated that while the program was academically most successful, our engineering physics faculty were disappointed when so

many of us went immediately on to graduate school. Their idea, at least in part, was that the then five-year undergraduate engineering physics program would allow a graduate to enter research or development activities directly, though not on as high a plane as graduates with doctorates.

Before "crystal-balling" the engineering educational needs of the 1980's we should decide what engineering really is. It seems to me that engineering is the application of physical science principles to the good of mankind. Admittedly the good of mankind needs some interpretation as well, since many of us are called upon to support the defense of our nation. Insight into the engineering needs of the 1980's must be drawn from what we know today. And the engineering of the 1980's will be about as similar to that of 1966 as the engineering of 1951, when we emerged from that first class, is to that of today. For example, in 1951 we built electronic instruments using vacuum tubes. In our engineering courses we learned how to take advantage of the idiosyncrosies of tubes and how to avoid their pitfalls. Not long afterward



we were exposed to some of the early thinking on how to put transistors to use. For the most part they were then curiosities, hard to control and unreliable when the temperature varied. Since then vacuum tubes have been displaced by transistors in most electronics applications, and transistors in turn are rapidly yielding to integrated circuits. Today's electronics engineer faces technologically a world which in many ways is completely new. For example, he thinks nothing of a digital computing system, which would have been the size



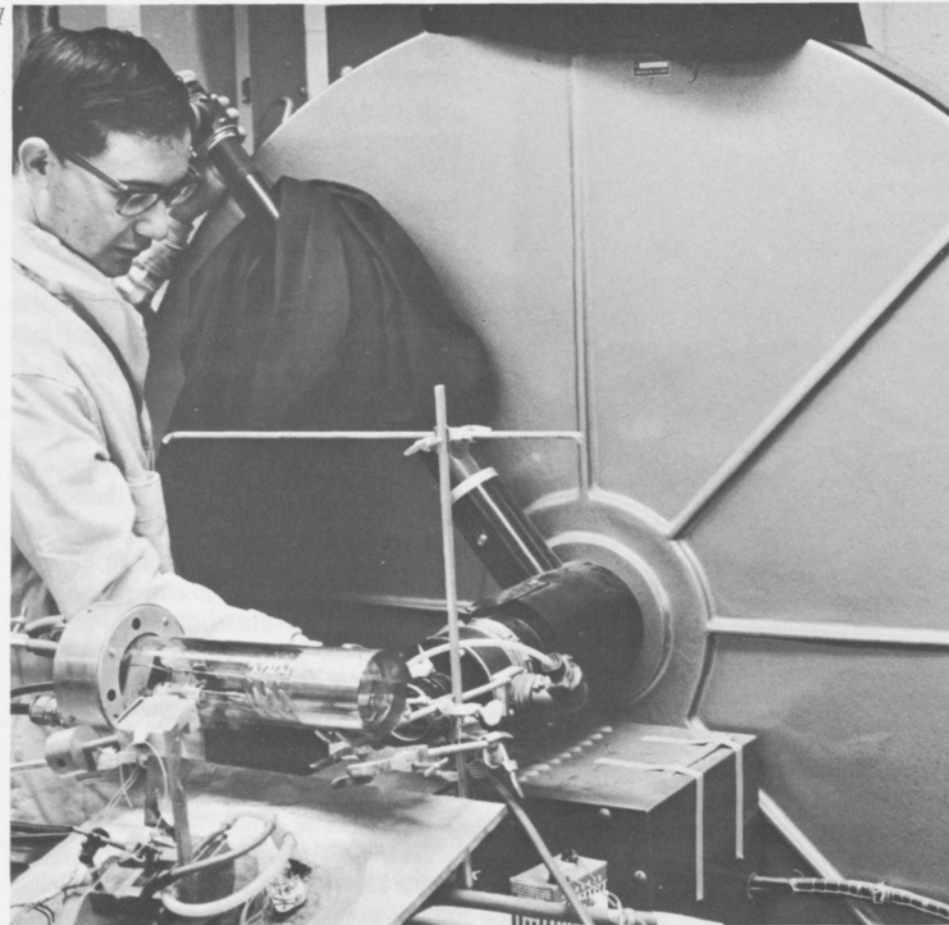
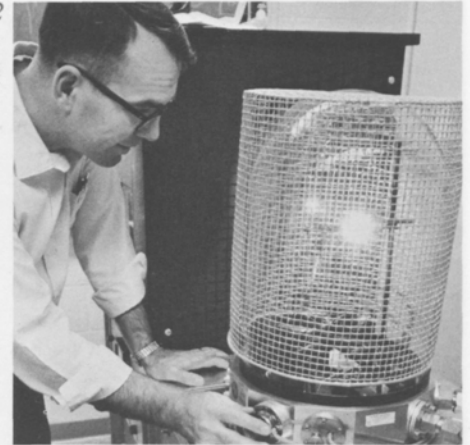
1. *Kenneth L. Bowles*

2. *Nuclear science and engineering educational and research programs at Cornell grew from the interests of engineering physics faculty members. The Nuclear Reactor Laboratory, shown here, is a result of the cooperative efforts of many individuals and organizations. The Atomic Energy Commission, the National Science Foundation, and the Cornell Aeronautical Laboratory provided financial assistance.*

BOWLES: A LOOK INTO THE FUTURE Needs of Engineering

An all purpose of Canada's first...

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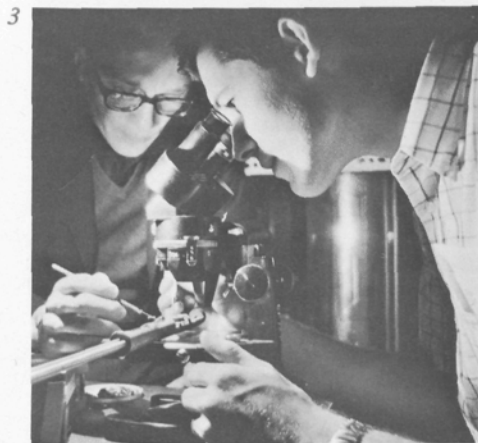


of a large room if built with vacuum tubes, which today with integrated circuits is the volume of an average man, works perhaps a thousand times faster, and costs not nearly as much as would the old tube device.

Today's problem then for the engineering educator could be compared to the problem of teaching our first engineering class in 1950 and 1951 to design equipment using the integrated circuits of the 1960's. No one dreamed at that time that the transistor would ever evolve into what it is today. But we must in our turn assume that even more dramatic developments are in store for us. Our educational system has to be designed somehow to respond to a technological environment whose time constant for change roughly equals that period spent by a student in obtaining his formal engineering education. To do this successfully suggests that the students should be furnished with a fundamental background and the opportunity to enhance their abilities *and* their inclinations to innovate. Each must emerge from his formal education able to acquire himself, through reading 16

Illustrative of applied physics graduate students' research interests are:

- 1. An ultra high-speed framing camera being aligned to photograph deformation during crack propagation in semi-plastic crystals.*
- 2. Vacuum deposition of thin film ferromagnetic material for electron microscope study of domain wall configuration.*
- 3. Measuring current distribution in a high field superconductor at liquid helium temperatures using magnetic flux quantum interferometer.*



and personal inquiry, all the information needed to accomplish the task that may interest him. In the face of an exponentially expanding fund of information, one's confidence in his capacity to accomplish something new needs to be sustained. Education cannot be cluttered with facts that may never be of use. Rather, a student needs to be taught how to attack any problem—starting with the fundamental principles, and learning along the way what others have done before him in assembling the details. He must be thorough

in researching his work in order not to end up re-inventing the umbrella!

That we cannot accomplish the whole job in a four- or five-year undergraduate program is obvious. What the undergraduate program can do is to furnish the preparation needed to pursue a graduate-level program. This preparation should include, I think, the following four particular ingredients:

1. Basic physical science facts
2. Beginnings of a logical approach to problem solving, including the mathematical tools
3. Motivation needed to carry a student into some specialty
4. Development of an attitude which will allow him to successfully work within a cooperative system.

A graduate-level program can be undertaken either in a graduate school or, in the case of some individuals, just as successfully in industry or a government laboratory. Any graduate-level type of effort should allow the beginner to try his wings in solving a new problem with generous assistance along the

way; this applies to those who go into basic work as well as those who do nothing but applied work.

To me, it seems—as part of a logical development—that it is important to teach any potential engineer or applied physicist to be pragmatic. While it is important to have an understanding of the elegance of pure mathematics or physics applied to a subtle problem, it is also essential that an engineer be taught to carry out the solution beyond this stage in order to accomplish his objectives.

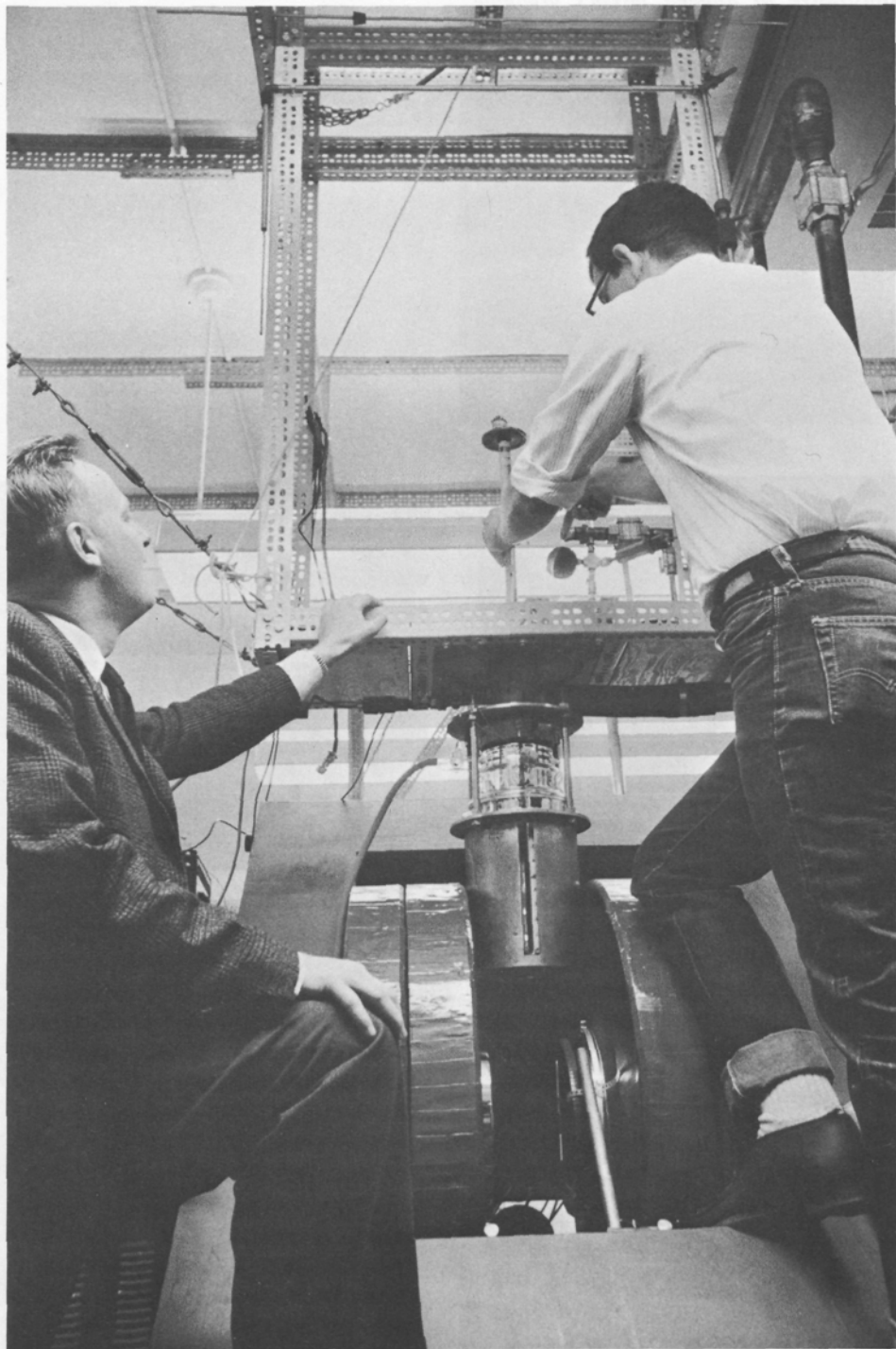
One shortcoming among most of the undergraduate programs with which I am familiar is the lack of a student's understanding of the random nature of most measurable quantities. Perhaps this is more strongly felt by those of us in communication theory or information science. To be sure, an effort at achieving such understanding may be made in a sophomore physics laboratory on errors in physical measurements—the bouncing ball experiments and the like—and a student may hear elsewhere about the uncertainty principle. But it seems indeed incredible that some



Research on superconductors presently under way:

1. *A superconducting magnet is installed in a cryostat to investigate current-carrying capability in high magnetic fields.*
2. *Professor John M. Silcox and his graduate students are studying surface currents in an oscillating magnetic field at low temperatures.*

Opposite page: Field ion microscopy reveals the details of atomic structure of metallic surfaces.



of our complex space efforts ever get off the ground when so few engineers are actually able to apply simple probability concepts to the marginal testing of components.

Now on to my third point—motivation. The 1980's will require a noticeable advance over today's efforts on at least two counts. First, while students in engineering or physical sciences progress considerably since their entry as freshmen, they emerge from their undergraduate years with only a very fuzzy picture of what the world of science and technology is all about. By the time much of the knowledge taught to undergraduates has been filtered through the teaching system, much of the excitement attached to real life application has been lost. We need to expose students to those top faculty members whose work has real relevance to the "outside world."

Let us consider a few specific examples that might drive home this point. You've all heard of lasers. The application of lasers to real problems is largely related to classical optics, yet many

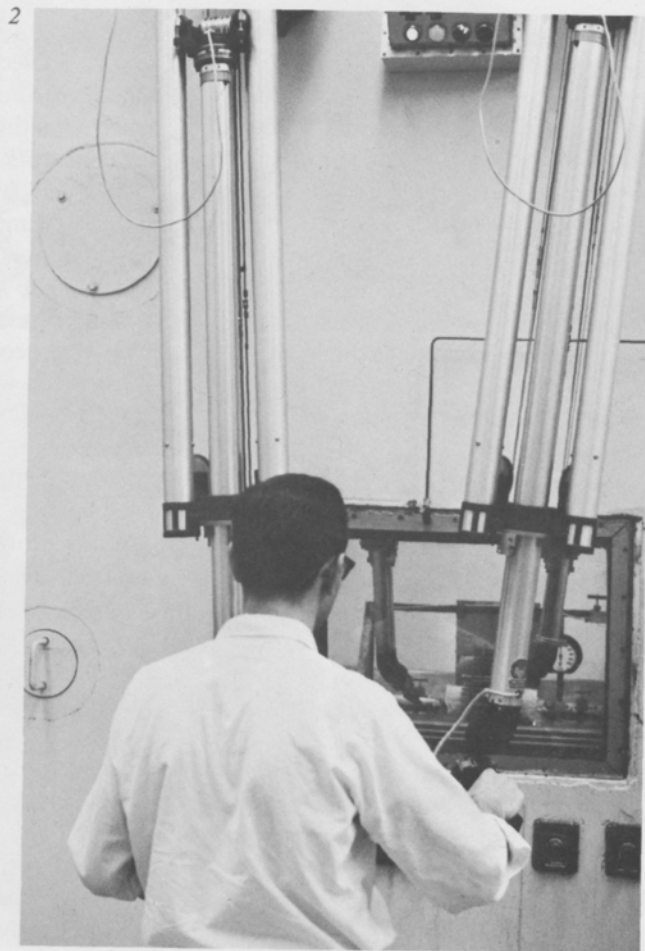
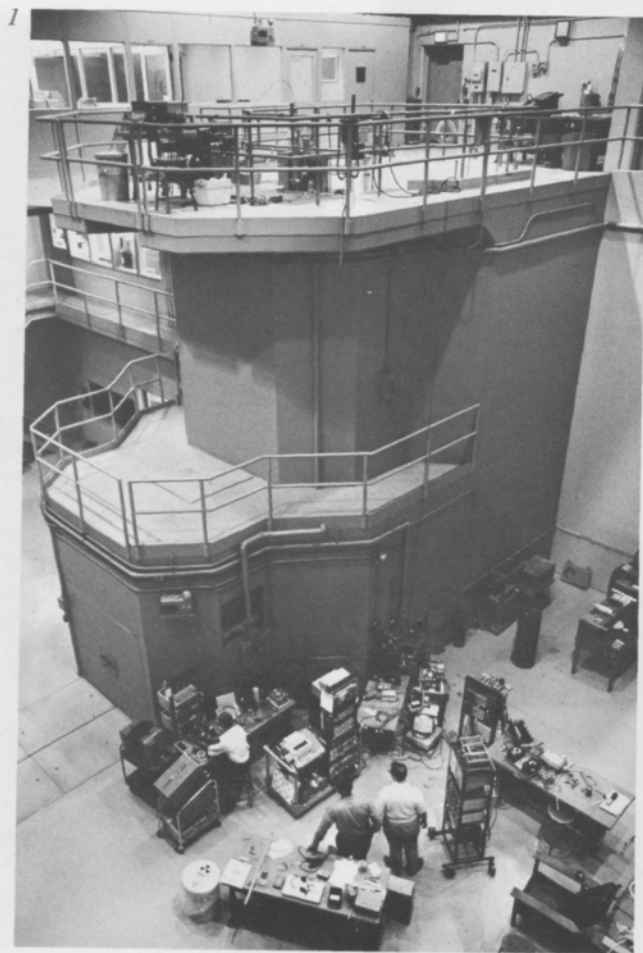
physics departments have ceased to teach optics. Optics is an "old fashioned" subject. Still, they object when an electrical engineering faculty tries to teach something about coherent objects for their work in holography.

Plasma physics has been supported in recent times because of the hope for plentiful generation of electric power. Most of the high energy aspects of the problem have been fairly well solved. The real problems are classical. They have to do with such things as the unstable behavior of the plasma, nonlinear reactions, and the like. Today we are finding that plasma physics methods are helping us to solve many other curious problems concerning the upper atmosphere. Plasma physics is classical physics, by and large, yet is frequently not taught in physics departments. It needs the talents of many more really brilliant applied physicists, and I'm happy to report that several of the leaders in the field today have come from Cornell's engineering physics program.

Still another example is that of geophysics, a field that has long been neglected by many of the really strong



*“We need many more people at the interface
between physics and engineering.”*





The facilities of the Nuclear Reactor Laboratory include a TRIGA reactor, gamma radiation cell, and a zero power reactor. The photographs to the left show:

1. A group of students utilizing one of the beam ports in the TRIGA reactor.
2. The "mechanical arms" adjusting a sample undergoing gamma radiation.
3. Above is shown the control panel of the zero power reactor used to study the dynamics of reactor instabilities.

classical physicists. I'm thinking of meteorology and upper atmosphere physics, solar system physics, seismology, oceanography, geomagnetism and, if you like, space physics—all areas in which important contributions can be made.

Two of my own experiences lead me to believe that our educational system could be doing much better to bring good people to fields like these. I've come here directly from a meeting of one of NASA's many sub-committees that formulate objectives of various scientific space missions. I must say

that it's very disappointing to see how many proposals must be rejected by such a committee because of good science and bad engineering, or good engineering and bad science combined. We need many more people at the interface between physics and engineering. Secondly, I have assisted a large, respected federal laboratory in finding new leadership—quality personnel—covering the whole spectrum of science and engineering. Considering the size of our national programs in these fields, we find the supply of such leadership very inadequate.

Now, the fourth point—teaching the student to work within a system. This may sound like heresy to you. Everyone knows that students know how to "work the system," but I suspect that its undercover nature on a campus leaves students without the right attitude toward realities when they begin working. Rather than trying to "lick them," we should "join them" and add some respectability to what is often a cooperative effort. So many of our science and engineering enterprises these days require the joint efforts of

very large numbers of people. They need to be prepared to contribute constructively to team problems. We need to prepare our students to face an interdependent system in some way which is less chaotic than the current practice. Students also need to be given some small degree of judgment and confidence which will allow them to become leaders, able to sort out the important from the unimportant and act accordingly.

Well, perhaps my crystal ball has been cloudy. Nevertheless, I have tried to convey the idea that the *important* engineering done in the 1980's will likely be done by the applied physicists. These efforts will be accomplished by methods which will more resemble those of the research physicist of today than those of the slide rule, nomograph engineer of yesterday. Engineering physics at Cornell holds a pivotal position, for it has access to good students and it can convince them that there are honorable careers in both classical and applied physics awaiting them.

KANTROWITZ: A LOOK INTO THE FUTURE

Research and Development in the 1980's



The exciting function of applied science and engineering is to form a bridge between science and social needs. The forming of this bridge requires the ability to meld a great number of academic disciplines. Is it not surprising, then, that as a result of the stress caused by trying to compress formal education into a finite time, one end or the other of this bridge suffers.

Immediately prior to World War II, engineering education was closely adapted to social needs then perceived. It was oriented to a vigorously growing and enormously productive industrial complex which made historic advances and showed the world the power of an industrialized society. At that time industry was largely based on 19th century science, and so it was not surprising that prewar engineering education reflected in its scientific base the science of the 19th century and earlier. This tendency to omit *new* science from the education of engineers has persisted in many instances even until today.

It was characteristic to find that prewar engineers had little to no working knowledge of advances being made in

atomic and nuclear physics. During the war it was very clearly demonstrated that leadership in the application of new science for social needs—in this instance, military needs—could not be undertaken by engineers who were unacquainted with modern science. As a result, leadership in *applying* such knowledge came from the pure scientist. Pure science thus acquired, and I might add merits, its immense prestige in education.

In the immediate postwar period, farsighted educators sought to correct this educational imbalance by providing a much wider scientific base in the undergraduate programs for engineering students. Men such as Cornell's Dean S. C. Hollister and Professors William Sears, Lloyd Smith, Trevor Cuykendall, and Henri Sack made a distinguished contribution to this effort by establishing and sustaining modern science-oriented programs in aerospace engineering and engineering physics. They and others with the same goals have done much to develop modern engineering leadership for today's modern science output.

Looking back over these past twenty

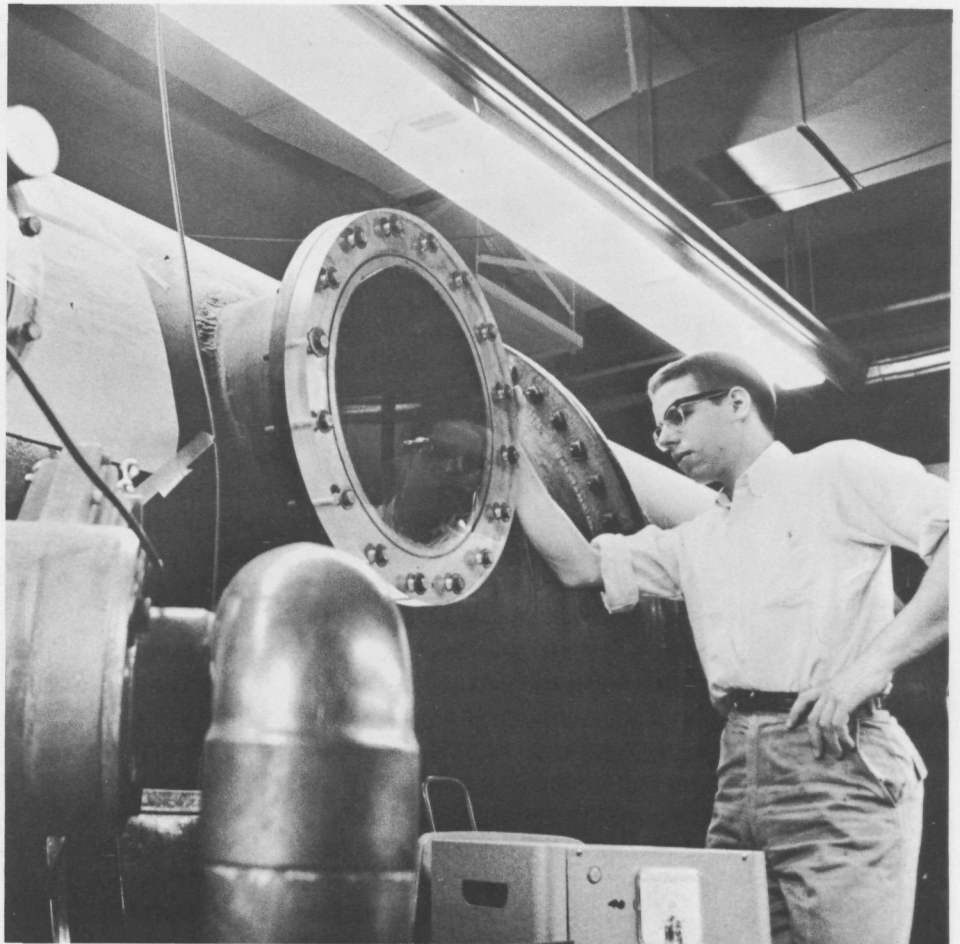
years though, I wonder whether we have gone too far in engineering education by emphasizing the scientific end of our bridge and minimizing attention to the social needs end. The process of introducing new science into engineering education, partly reflecting the prestige currently enjoyed by pure scientists, has now progressed to the point where it may be completely dominating the curricula. In so doing, the motivation that needs to stem from each end of our bridge becomes displaced. Furthermore, one finds too frequently on college campuses today a kind of value judgment placed on engineering and on engineering faculties, a judgment which is related exclusively to the degree of scientific sophistication of faculty research interest. Insofar as this evaluation becomes the exclusive or dominant one, the point of engineering—the excitement of being an engineer—has been lost. In the next two decades, then, we face the task of adjusting this balance again—not to lose contact with science, but to ensure that social needs are being discerned and met.

Those of us in my kind of work, 22



Above: Arthur R. Kantrowitz.

Right: The plasma wind tunnel is one of the new major facilities for experimental research in the Graduate School of Aerospace Engineering. It will be used to conduct experiments on collisionless shocks and other plasma waves.

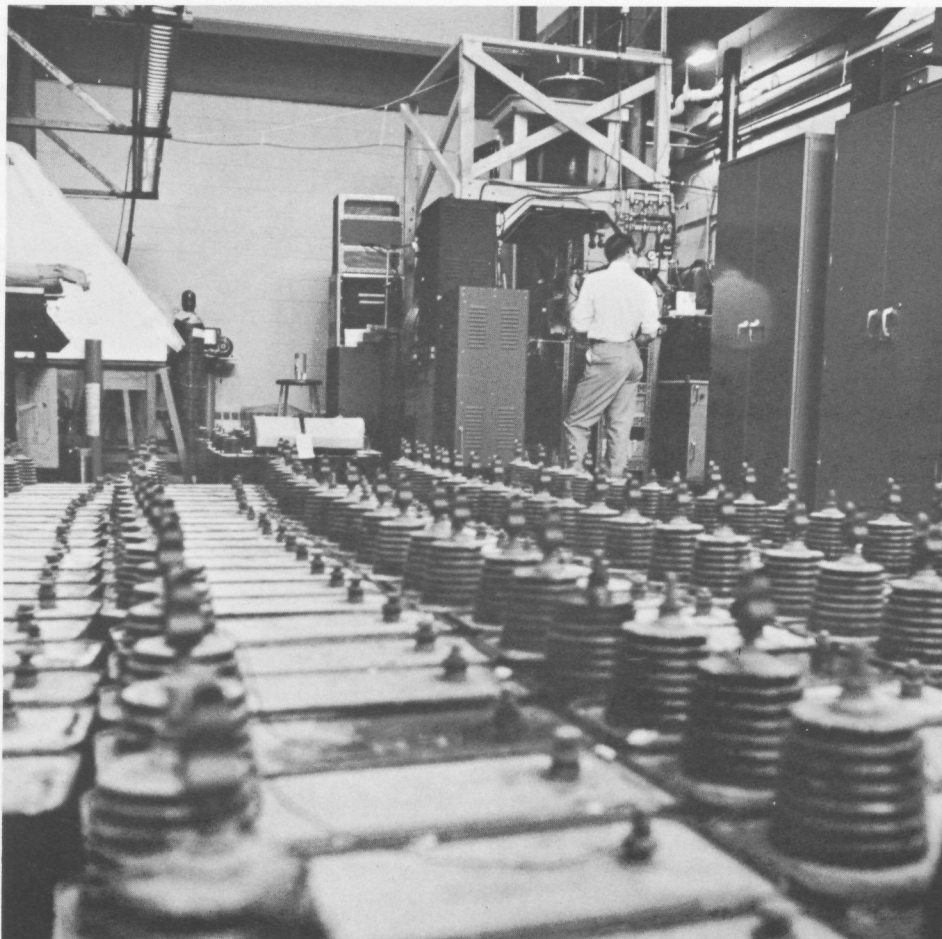


KANTROWITZ: A LOOK INTO THE FUTURE Research and Development in the 1980's

when looking for people frequently find ourselves faced with a choice among two types. First there are the well-trained engineers who have little acquaintance with modern science, yet are motivated toward work with social impact. Secondly there are those well equipped in modern science who have little interest in doing something simply because it fills a social need.

The problem then for engineering educators is to educate a person to recognize and be inspired by the challenge of merging science with social needs. It may well be that some of this inspiration should be induced by out-of-school industrial experiences—and I don't mean just a summer job! In this way today's student will be sincerely motivated to serve social purposes, rather than to serve them merely as a way to earn a living.

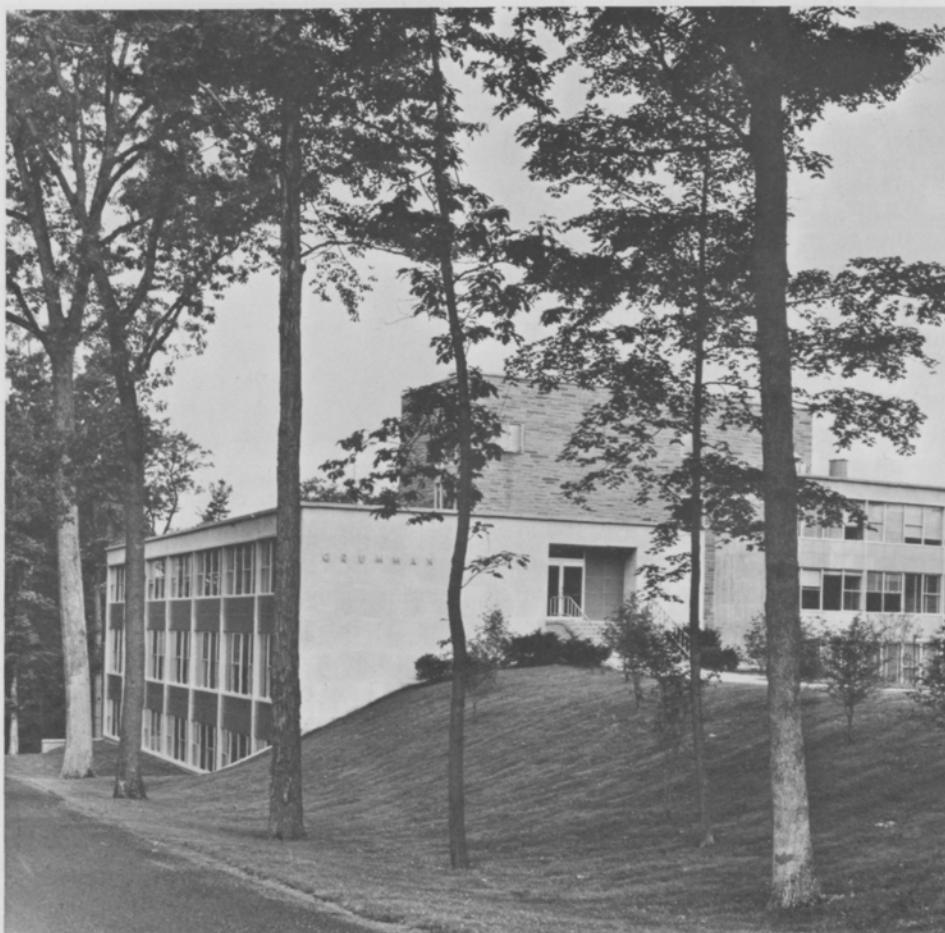
What will be the character of academic research in the next twenty years? The prime vehicle is of course federal sponsorship of research and development, applied first on a large scale in defense, then in space, and more recently in medicine. It is likely that this sponsorship will be extended



Left: In the foreground are capacitors required to charge the plasma wind tunnel; in the background a student works on the apparatus used to generate an argon plasma atmosphere operating at approximately 8,000° K in one atmosphere pressure.

Opposite page: Gift of Leroy R. Grumman '16, Grumman Hall, houses the laboratories of the Graduate School of Aerospace Engineering.

“Engineering education should increase interaction with the social sciences and the humanities so that graduates... may be inspired...to relate science to a rapidly changing society.”



to other perceived social needs, such as control of our environment. This federal funding has stimulated the development of university research in applied science as well as in areas of pure science. However, it has become clear in recent years that the nonacademic institutions will have to bear the prime load in responding to the needs of society for new technology. Industry and government and their laboratories need to be continually educated as to what is important to the non-academic world.

Academic research *must*, in these years ahead, reflect greater awareness of the importance of making contact with both ends of the bridge, particularly the end of social needs. Engineering education should increase interaction with the social sciences and the humanities so that graduates of our leading institutions may be inspired by this call to relate science to a rapidly changing society. The great problem for tomorrow's graduate is to marshal a presently amorphous social need and to make sound decisions that will enable all of technology to respond.

THE NEXT TWENTY YEARS IN AERONAUTICS AND SPACE

By Mac C. Adams

At the time the Engineering Physics and Aerospace Engineering programs were established at Cornell University in 1946, the United States was shedding its military cloak and beginning a new era of peaceful pursuits. We had begun to use captured German V-2 rockets for upper atmosphere research – some sixty V-2's were fired – and it became increasingly apparent that we needed rockets of our own design for continued research. The war of course had stimulated a large growth in aviation, which had reached a new peak of activity by 1946. Production of aircraft had risen from 500 a month early in 1940 to a high of 9,000 a month in 1944. Airplanes had become transportation workhorses during the war, and postwar air travel had begun to boom.

In his 1945 Wilbur Wright Memorial Lecture, Theodore P. Wright, a family descendant, made a number of ten-year projections for aircraft usage. He estimated, for example, that the number of domestic air passengers would rise from six million in 1945 to twenty million in 1955. Events proved him conservative: by 1955 the number of passengers

reached thirty-eight million, almost twice his estimate. In 1965, United States airlines carried ninety-five million passengers, and in terms of passenger miles, air travel far surpassed that of railroads and buses combined.

We are, I believe, on the threshold of another large upswing in *civil aviation*. Airlines are expected to double their present traffic in the next five years. Studies of population growth predict that by 1985 there will be three super-metropolitan centers in the United States. These are the corridors between Boston and Washington, Chicago and Buffalo, and San Francisco and Los Angeles, with an estimated 130 million people within them. An increasing demand for versatile *short-haul* transports to serve these areas and to provide transportation to and from large airports for transcontinental and trans-oceanic trips is apparent.

Another threshold awaits us: *long-range, high-speed transport* for travel between major cities of the world. Let us look for a moment at the progress made by aviation in the past twenty years and then look twenty years ahead.



For comparison, consider a four-hour period for making a trip, allowing half of this time for travel to and from air terminals and for loading and unloading. Twenty years ago, the DC-4, with a cruising speed of 200 miles per hour, would have enabled us to fly from New York to Detroit in four hours. Today, the 707, flying at almost 600 miles an hour, takes us from New York to Miami in this same four-hour period. In the seventies, with supersonic transports, it will be a four-hour trip from New York to London. And in the

eighties, with hypersonic aircraft, a trip from New York to Tokyo or Australia will require only four hours. Hypersonic transports, traveling at 4,000 to 7,000 miles per hour compared with the 2,000 miles per hour of the supersonic transports, will be able to travel halfway around the world, non-stop, and do so economically.

However, before such aircraft become a reality, problems must be solved in propulsion, materials, and structures. For example, some areas of the airframe must sustain 3,000° F. temperatures, and "cool" regions will operate at 1,300° F.

Let us now turn to space exploration, which is less than ten years old. From Shephard and Glenn to Stafford and Cernan, our astronauts have demonstrated their ability to function effectively for up to two weeks in space, to rendezvous with other spacecraft, to go outside the capsule, and to adapt themselves to new situations in emergencies. Unmanned spacecraft have probed the space environment, taken pictures of the moon and Mars, and measured characteristics of Venus and the sun.

Surveyor did an amazing job of transmitting thousands of pictures of the lunar surface.

Then, too, operational satellites are sending daily reports on cloud cover over the entire world, and communication by satellites is available between Western Europe, North America, and the Pacific. The research that made these accomplishments possible was done many years ago. *Today's research must be directed to the needs of space flights ten or more years away.* Such long lead times are necessary if we are to obtain the technology needed for the orderly planning, budgeting, and realization of future space vehicles.

To illustrate a few of the many aspects of today's space effort and its relationship to the future, suppose we take an imaginary voyage to the planet Mars. The trip will last about one and a half years and will require probably an eight-man crew. The huge spacecraft needed will be boosted into Earth orbit by means of large chemical rockets. It will be assembled and checked out in orbit, then nuclear engines will accelerate it into a trajectory toward

Mars. On the way, course adjustments requiring highly accurate guidance means will be made with small rockets. Once in orbit around Mars, a landing craft will leave the mother ship and descend to the surface. Upon completion of surface exploration, the astronauts will return to the orbiting mother ship and the spacecraft depart for the Earth again, using nuclear propulsion. On the way back to Earth, accurate guidance and navigation would be essential for the returning spacecraft to enter a narrow corridor, use the Earth's atmosphere for slowdown, and then land at a desirable location.

Let us consider some of the problems associated with such a trip, including the chemical and nuclear propulsion system, life support and space hazards, communications, landing and astronaut mobility, Venus swingby, atmosphere entry, and landing.

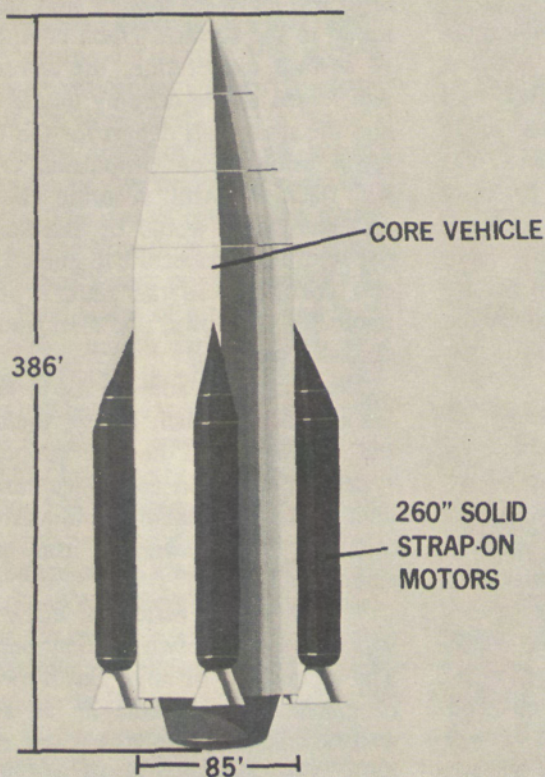
The Mars spacecraft for eight men will weigh about two million pounds. The technology of large Earth-to-orbit chemical boosters must be advanced well beyond our present booster capability. One proposal is to use liquid

THE NEXT TWENTY YEARS IN AERONAUTICS AND SPACE

By Mac C. Aspin

Figure 1

LARGE LAUNCH VEHICLE STUDY CONFIGURATION



ORBITAL PAYLOAD - 1.7 M LBS
LAUNCH WEIGHT - 50.7 M LBS.

	BOOST STAGE	CORE ENGINES
MOTOR OR ENGINE TYPE	260 IN.	CRYO./LIQ.
NO. OF UNITS	4	
PROPELLANTS	SOLID	H ₂ /O ₂
WEIGHT - LBS		
STAGE	18 M	31 M
THRUST		
STAGE TOTAL	32 M	36 M
PER MOTOR	8 M	

“Life support is a key technology for a Mars flight or any other long-duration future space flights.”

hydrogen – liquid oxygen engines for the central core, and four 260-inch solid strap-on motors for auxiliary thrust. A rocket this large would be 386 feet high and eighty-five feet in diameter, and would have a total thrust of sixty-eight million pounds, a thrust nine times greater than the Saturn V and more than 400 times greater than the booster for Explorer I, our first orbiting satellite.

As shown in Figure 1, the size of the “small” strap-on solid motors for the large booster dwarfs an average automobile. Each of these “small” motors will produce a thrust of seven and a half million pounds. If nuclear propulsion achieved by the solid motors is used to leave the Earth orbit and proceed toward Mars, the Earth orbit weight would approximately double. Several nuclear propulsion modules would be clustered together and connected with other parts of the spacecraft, such as the crew compartment, Mars lander, and Earth return vehicle.

To assemble this very large spacecraft will require a number of rendezvous operations in space. Information

and now from the Apollo program, is essential for such future orbital operations. The success of the Gemini missions has dispelled doubts that may have lingered about the feasibility of space rendezvous.

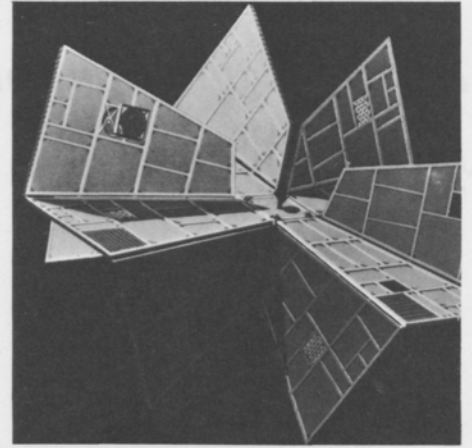
Rendezvous of spacecraft, however, is only part of the total procedure. Man must learn how to go from one spacecraft to another, how to assemble several spacecraft or elements together, how to transfer propellants and other supplies, and how to rescue a fellow astronaut in difficulty. The space walks of White and Cernan were the first United States attempts of this essential activity. These experiments demonstrated the ease with which it is possible to get outside the capsule and move about, but they also demonstrated the need for more positive astronaut motion control.

Life support is a key technology for a Mars flight or any other long-duration future space flights. Fresh air, water, food, heat, and a certain amount of humidity must be supplied; carbon dioxide, body waste, odors, and gases from equipment, heat, and other harm-

ful substances must be removed. In present space missions, the life support wastes are discarded after forming. These are called “open” systems. Gemini and Apollo are of this type and provide for fourteen-day missions. For trips of long duration, however, the supplies needed become so great that wastes must be treated to salvage certain basic ingredients such as oxygen and water. Later, more complex systems will be used.

As the spacecraft proceeds on its course, astronauts and equipment must be able to function effectively in a hostile environment which includes zero gravity, radiation, and meteoroids. In particular, man’s performance under zero gravity must be understood better, and some amount of artificial gravity may well be needed. Radiation and meteoroids, too, are potential hazards and both are receiving considerable attention. Last year three Pegasus satellites were launched to study meteoroids in the near-Earth environment. More than 1,100 punctures have been recorded. The data confirm the Apollo design, and additionally provide infor-

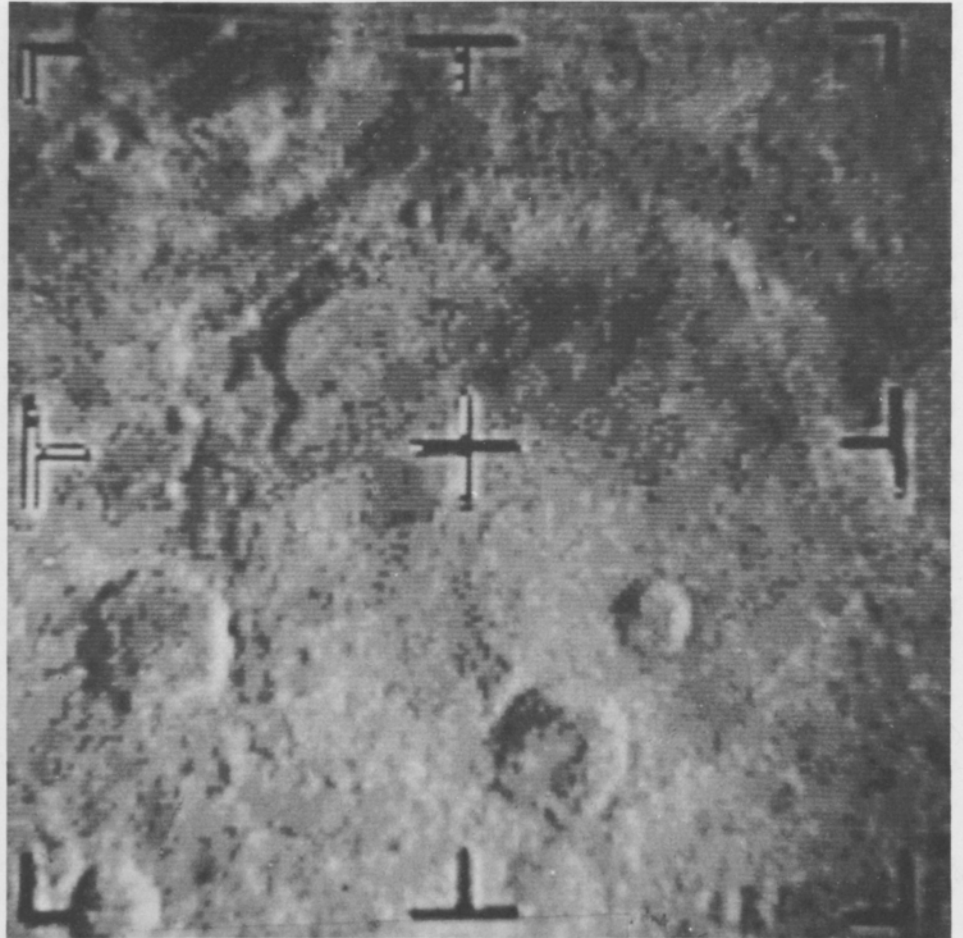
Figure 2



mation to designers of future spacecraft. New satellite concepts are under investigation to study meteoroids at planetary distances and the asteroid belt beyond Mars. The configuration shown in Figure 2 would have 6,000 square feet of exposed surface and would be launched by a Saturn V.

When the landing craft leaves the orbiting mother ship, it will use for deceleration the Martian atmosphere, which has about one-one hundredth the pressure of the Earth's atmosphere; near the surface, the lander will need rocket propulsion for final maneuver and touchdown. Once man is on the Martian surface, which has four-tenths of the Earth's gravitational pull, he will be able to move about with considerable ease. Studies of locomotion under low gravity conditions and of landing techniques in different fields of gravity are currently under way. While man is exploring the Martian surface, he will be able to communicate fairly easily with the orbiting mother ship, but communication with Earth on a real time basis will be very difficult because of the great distance to be covered.

Figure 3



Mariner IV sent back the photograph of Mars shown in Figure 3. It was transmitted at the rate of eight and a third bits per second, with eight and a half hours required to transmit this one picture. Real time television would require a data rate of six million bits per second, which presents a genuine challenge to the researcher. Advanced lasers may well provide a more promising method for communicating such high data rates by optical methods.

As previously mentioned, the returning spacecraft would swing closely by Venus, in order to make use of the planet's gravity to deflect the trajectory and improve the approach angle to the Earth's orbit. This "swingby" technique greatly reduces the entry speed as the spacecraft approaches Earth. If the returning spacecraft leaves Mars and passes by Venus, it arrives at Earth at a 14° approach angle traveling at 44,000 feet per second. If a direct return path is chosen, the spacecraft arrives at Earth at an angle of 31° and an entry velocity of 65,000 feet per second; this would add considerably to entry heating problems. The study of attrac-

tive planetary entry configurations is just beginning, but we know the shape will be more slender than the blunt configurations of Gemini and Apollo.

Our imaginary voyage to Mars is now over. We have merely considered a few areas in which substantial technical advancement will be required to ensure a successful "maiden voyage." This trip, coupled with man's increasing use of air transportation on Earth, suggests there are exciting and productive days ahead for the whole aerospace team. Past achievements in aeronautics and in space have made possible what was thought to be impossible; the rate of our present-day achievements suggests that the time required to accomplish the impossible will be shortened.

Mac C. Adams is Associate Administrator for Advanced Research and Technology, National Aeronautics and Space Administration. He earned his B.S. in mechanical engineering in 1946, and his M.Aero.E. in 1949 and Ph.D. in 1953 in aerospace engineering, all at Cornell University.

Formerly deputy director of Avco's Everett Research Laboratory, he was voted one of America's "Ten Outstanding Young Men" of 1960 by the United States Junior Chamber of Commerce. He is a member of the American Institute of Aeronautics and Astronautics, Sigma Xi, and Tau Beta Pi.

Figures 1, 2, and 3 courtesy of National Aeronautics and Space Administration.

REGISTER

■ "It was one of the best-kept secrets of my own twenty-year association with the University," Andrew Schultz, Jr., Cornell's Dean of Engineering said. Then he went on to read the following citation:

"This is to inform you, Trevor R. Cuykendall, that the Executive Committee of the Board of Trustees of Cornell University at a meeting held today, June 11, 1966, elected you to the Spencer T. Olin Professorship of Engineering."

Awarding a distinguished chair to a faculty member is one of the most significant honors that any university can bestow. The citation was all the more satisfying to the audience gathered to honor the engineering physics and aerospace engineering programs because Dr. Cuykendall had played such an important role in Cornell's engineering physics program, not only in its establishment, but also in sustaining the program over its twenty-year history.

Professor Cuykendall came to Cornell in 1929 as a physics instructor from the University of Denver where he had received his B.S. in electrical engineering and his M.S. in physics. In 1935, he obtained his Ph.D. in physics and math-

ematics at Cornell. For the next three years he was a research associate in engineering and was made assistant professor in engineering in 1939. He then joined the Naval Ordnance Laboratory for two years as a senior scientist in 1941, and from there went to the Los Alamos Scientific Laboratory until his return to Cornell in 1946.

It was in 1946, under the leadership of S. C. Hollister, then Dean of Engineering, that the team of Smith, Sack, and Cuykendall founded and developed the initial engineering physics curriculum. (Lloyd P. Smith is Vice-President of Physics and Applied Sciences at Stanford Research Institute; Henri Sack is now Walter S. Carpenter, Jr. Professor of Engineering at Cornell.) Named Professor of Engineering Physics in 1949, Dr. Cuykendall served as director of the Department of Engineering Physics from 1956 through 1962.

While on sabbatic leave in 1950, he joined the faculty of the Oak Ridge School of Reactor Technology and studied the measurement of the resonance escape integral in uranium. Subsequently, he initiated the first nuclear engineering course at Cornell in 1952 and

later was responsible for developing both the graduate major in nuclear science and engineering and the Nuclear Reactor Laboratory. (See page 20.) He worked with the experimental reactor physics group at Brookhaven during 1958 and was director of the American Society for Engineering Education - Atomic Energy Commission's Faculty Summer Institute on Nuclear Engineering in 1959 and 1960. Since 1963, he has also been a consultant to the AEC's division of nuclear education and training.

Long active in educational policy matters, Dr. Cuykendall has been chairman of the American Society for Engineering Education committee on relations with the Atomic Energy Commission since 1962, and was chairman of the Nuclear Science and Engineering Fellowship Board of ORINS-AEC in 1964-65. Presently, he is the chairman of the AEC panel on Nuclear Science and Engineering Traineeship Administration.

Professor Cuykendall is a fellow of the American Physical Society, and a member of the American Nuclear Society, American Society for Engineering

Education, Tau Beta Pi, Sigma XI, and Phi Kappa Phi. He has published more than twenty-five research papers on applied physics and engineering.

Since his Colorado youth, Professor Cuykendall has enjoyed the mountains and has had considerable interest in the early western railroad era. He and his wife Muriel have a son, Robert, employed by Hughes Aircraft in Los Angeles, and a daughter, Mary, who resides in Cobleskill, New York.

The chair he now holds was established with grants from Spencer T. Olin, noted industrialist, and the Ford Foundation. Since Mr. Olin has long expressed his concern for the quality of undergraduate education, the selection of Professor Cuykendall for the chair was all the more significant. "Men who are willing to fight curricular restrictions when they exist, who are willing to spend the time and effort with individual students to bring them successfully through a challenging curriculum, and who are concerned with curricular matters," Dean Schultz remarked, "are some of the qualities that are paramount in the selection of chair recipients."



and public service only further our competence and capacities to achieve this purpose. In addition to his Cornell honor, Dr. Cuykendall was awarded the "Distinguished Alumnus Award" by the University of Denver in 1962.

Perhaps the remarks he made immediately after the citation best reflect his modesty, warmth, and integrity—qualities well-known to those who have been associated with him.

"Fellow Cornellians, this certainly has been a very well-kept secret. I am completely nonplussed and very happy. The enjoyment of working here for these many years has been ample reward for my services to Cornell. It has been great fun to work with the students and staff; I hope that I'll have at least a few more such years. Thank you very much."

■ *Everett M. Strong*, Professor of Electrical Engineering, received the Illuminating Engineering Society's Gold Medal "in recognition of distinguished leadership in fruitful research programs in light and vision" in August, 1966. A fellow of the Society, he was national president in 1952-53.



Strong received his B.S. degree in electrical engineering from M.I.T. in 1922. Following two years as an illuminating engineer with General Electric, he joined the Cornell faculty as an instructor in illumination. Professor Strong developed the Engineering Co-operative Program twenty years ago, and has been the director since its beginning. The program now deals actively with twelve companies, and this year involves sixty-four students.

Professor Strong was a United States delegate for the State Department to the V.H.F. Maritime Radio Telephony Conference at the Hague in 1957, and to the I.T.U. Administrative Radio Conference at Geneva in 1959. He was also a United States delegate for the Illuminating Engineering Society to the Commission Internationale de L'Eclairage conferences at Brussels in 1959 and at Vienna in 1963.

Professor Strong is a member of the Trustees of the Illuminating Engineering Research Institute and a member of the American Society for Engineering Education. He has been a licensed engineer in New York State since 1936. Professor Strong is listed in American Men of Science, Who's Who in the East, Who's Who in America, Who's Who in Education, and World Biography. He is also a member of Tau Beta Pi, Sigma Xi, and Eta Kappa Nu.

■ *Mark S. Nelkin*, Associate Professor of Engineering Physics, was named co-winner of the American Nuclear Society Special Award for 1966 for "his outstanding contributions to reactor physics" at the Society's 12th annual meeting in Denver, Colorado in June. The accompanying citation reads: "His theoretical work on neutron



thermalization and thermal spectra have been the basis for revolutionary advances in this important field. Before he started, only the crudest models were available for analysis; now, and owing largely to his efforts, a reasonable model of and insight into thermal spectrum is accessible to the reactor designer."

Professor Nelkin was graduated from M.I.T. with an S.B. degree in physics in 1951. As a National Science Fellow at Cornell, he earned a Ph.D. degree in physics in 1955. He joined the Cornell faculty in 1962, after seven years' industrial experience with Knolls Atomic Power Laboratory and the General Atomic Division of General Dynamics. His present research interests are neutron scattering, and transport and kinetic theory.

Professor Nelkin has been an official United States delegate to the 1958 Geneva "Atoms for Peace" Conference and to the International Atomic Energy Agency Conference in Vienna in 1960. He is the author of many articles on neutron thermalization and related topics. Professor Nelkin is a member of the American Nuclear Society, the American Physical Society, and Sigma Xi.

FACULTY PUBLICATIONS

The following publications and conference papers by members of the Cornell College of Engineering faculty were published during May, June, and July 1966. In cases of co-authorship, the names of Cornell faculty members are in italics.

■ AEROSPACE ENGINEERING

de Boer, P. C. T., "Probe for Measuring Ion Density in Slightly Ionized High Speed Flow," *Review of Scientific Instruments*, Vol. 37, No. 6 (June 1966), pp. 775-785.

de Boer, P. C. T., Rev. 3264, *Applied Mechanics Review* 19, No. 5 May 1966.

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TWO DECADES

Graduate School of Aerospace Engineering
Department of Engineering Physics

By Donald F. Berth

Twenty years ago, Cornell's College of Engineering launched what are today its highly successful degree programs in aerospace engineering and engineering physics. One of the aims of both programs was to prepare graduates who could function at the interface of engineering and science, and thereby shorten the time between "idea" and "application." The rapid changes that took place in the traditional engineering technologies of the early 1940's in response to the scientific and technical demands of World War II, had forced many engineers practicing at that time to sideline positions in the development of the new technologies. While there were, and still are, continuing opportunities for men educated in the more traditional and established areas of engineering, the scientific and technical outgrowth resulting from the war years called for the kind of education that would enable men with an engineering background to play a major role in developing new technologies.

Fortunately, Cornell had able men to initiate and sustain such progressive programs. William R. Sears became professor and first director of what is now

called the Graduate School of Aerospace Engineering in 1946, and he served in the latter capacity until 1963. Professor Sears observed that much of the time the engineer works in an area where there is little science to lean upon, and certainly none in detail. This was particularly true for aeronautical engineers. The School he led was established to bring together principles of aeronautical science and engineering and to teach them as one discipline. From the beginning, the philosophies and programs of this undertaking have been innovative and bold.

Of engineering physics, Cornell's S.C. Hollister, Dean of Engineering, Emeritus, speaking at the Twentieth Anniversary Program banquet last June, said, "It was a real challenge to build engineering physics because there were people who looked down upon science from one side and there were people who certainly looked down upon engineering from the other side. The challenge was to establish a harmonious and energetic intellectual attack on the whole situation. Lloyd P. Smith, Henri S. Sack, and Trevor R. Cuykendall are the three men

who have built the department of engineering physics to the position it now holds. It is a vigorous program—one that has contributed much in the way of infusion of scientific insight into the engineering operation."

The success of any educational program can be measured by the competence of its graduates. Their professional commitment and abilities should reflect the quality of their education. Talented students and dedicated faculty, working in a stimulating environment, are a combination heavily weighted in favor of success, and in both the aerospace and engineering physics programs such a combination has been present.

AEROSPACE ENGINEERING

The prospects of aircraft, bolstered by military demands during World War II and, later, by promising commercial uses, suggested to educators that aeronautical engineering should be treated as a discipline apart from traditional engineering programs. While instruction in aeronautics had previously been given for many years in Cornell's Sibley

The three men chiefly responsible for the development of the Department of Engineering Physics are shown participating in events of the 20th Anniversary Program.

1. Alumni review early developments in engineering physics with Lloyd P. Smith, now at Stanford Research Institute.

2. Henri S. Sack (left), Walter S. Carpenter, Jr. Professor of Engineering, pauses with Leo Steg (Cornell Ph.D., '61), editor of the Journal of Aeronautics and Astronautics, during the tour of Clark Hall.

5. Trevor R. Cuykendall (left), Spencer T. Olin Professor of Engineering, and John F. McManus, Assistant Dean of Engineering at Cornell, at the luncheon for engineering physics alumni held in the Dexter Kimball Room of Willard Straight Hall.

Alumni, faculty, and outstanding men in the field, assembled for the Twentieth Anniversary Program of the Graduate School of Aerospace Engineering.

3. William R. Sears (right), Director of the Graduate School of Aerospace Engineering for seventeen years, and now John La Porte Given Professor of Engineering, talks with Mac C. Adams, deputy director of the National Aeronautics and Space Administration, just before the aerospace engineering-engineering physics banquet.

4. Edwin L. Resler, Jr., a former student of Dr. Sears, and the present Director of the Graduate School of Aerospace Engineering, at work in his office.



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School of Mechanical Engineering, it was not until 1946 that the Graduate School of Aeronautical Engineering (later to become Aerospace Engineering, reflecting the broadened objectives of the School) was established.

Aeronautics was not new to Cornelians. Several alumni had been prominent in aeronautics prior to the establishment of the School; among them were Leroy R. Grumman, founder of the aircraft firm bearing his name; J. Carlton Ward, general manager of Pratt & Whitney Aircraft and later president of Fairchild Engine and Airplane Corporation; Victor Emanuel, chairman of Avco Manufacturing, which at one time owned Convair; and George P. Lewis, director of aeronautical research for the National Advisory Committee for Aeronautics (predecessor of the National Aeronautics and Space Administration).

The School's primary objective was stated as "the training of selected engineering and science graduates in the more scientific aspects of aeronautics. . . . It is intended especially to prepare graduates to carry out research and development engineering of high quality in the aeronautical and related industries,

and in aeronautical scientific institutions."

The Aerospace Engineering faculty has characteristically reached beyond conventional, immediate theories and practices in order to impart to each student a fundamental yet progressive background of analytical techniques, which will prove useful whatever direction modern aerospace engineering development takes. Change is ever present and today's course descriptions bear little resemblance to the initial offerings: advanced kinetic theory, high temperature gasdynamics, magnetohydrodynamics, hypersonic flow theory, viscous flow theory, compared with the earlier theoretical aerodynamics, airplane design, mechanics of jets, airplane mechanics, and aerodynamics of power plants.

Research is presently carried out in four areas: fluid mechanics, high temperature gasdynamics, magnetohydrodynamics, and space mechanics, whereas the School's early research efforts were directed toward supersonic and hypersonic aerodynamics problems.

During its twenty years of existence, the Graduate School of Aerospace Engineering has awarded 139 Master's de-

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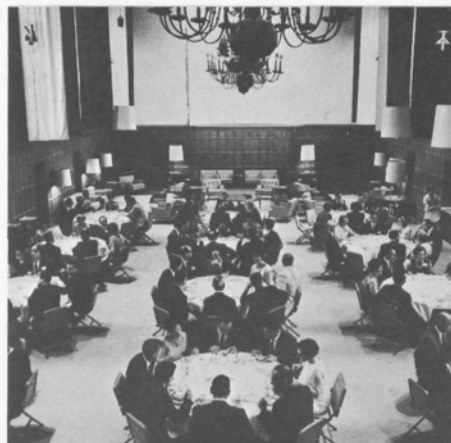
degrees, twenty-seven of which have been the professional degree, Master of Engineering (Aerospace), and sixty-five Ph.D.'s. About one-third of the Master's theses have resulted in published papers; an even more impressive fifty-seven of the sixty-five Ph.D. theses were published in one form or another. As for occupational pursuits of Aerospace alumni, some examples are given below:

a senior experimental test pilot at Boeing (delivered the first Boeing 707 to Berlin; now teaches air crews for airlines and governments)

the deputy director of NASA, in charge of research programs (voted one of the nation's "Ten Outstanding Young Men" in 1960 by the United States Junior Chamber of Commerce)

a professor at the Technion—Israel Institute of Technology, Haifa (a native of Israel and a Cornell coed civil engineering graduate)

the president of Therm Advanced Research (a research and development firm principally dealing with fluid dynamics problems)



The Memorial Room of Williard Straight Hall was the setting for the aerospace engineering luncheon.

the director of aerodynamics and propulsion research laboratories at Aerospace Corporation

The 204 degrees awarded by the School were earned by about 150 individuals, some receiving both a Master's and a Ph.D. degree. Approximately two-thirds are now employed in industrial or government research and development laboratories; the balance are college or university faculty members. Among the major research and development employers, at least four aerospace graduates are presently with each of the following organizations:

<i>Name</i>	<i>Number of Aerospace Engineering Alumni</i>
Aerospace Corporation	9
Avco—Everett	10
Avco—Missiles and Space Division	4
Boeing	6
Cornell Aeronautical Laboratory	7
Douglas Aircraft	5
General Electric	4
Grumman Aircraft	4
NASA	8
Therm, Inc.	6

Other employers with fewer Cornell aerospace graduates include: Aeronautics, Batelle, Hughes, Jet Propulsion Laboratory, Lawrence Radiation Laboratory, Lockheed, Martin-Marietta, Northrop, Sandia, TRW, and United Aircraft.

The forty-eight aerospace alumni who have gone into teaching are situated at thirty colleges and universities. Cornell and the Massachusetts Institute of Technology, with eight and six Cornell graduates respectively, head a list that also includes the University of Alabama, the Air Force Institute of Technology (at Wright-Patterson A.F.B.), Brown University, State University of New York at Buffalo, University of California at La Jolla and at Los Angeles. The Catholic University of America, New York State University College at Cortland, Dartmouth College, University of Detroit, Iowa State University, The University of Michigan, New York University, Polytechnic Institute of Brooklyn, Princeton University, Purdue University, Rensselaer Polytechnic Institute, University of Rochester, San Diego State College, University of Southern California, The University of Toledo, United

States Naval Academy, United States Naval Postgraduate School, University of Washington, The University of Wisconsin, Rhenish-Westphalian Technical University in Aachen (Germany), and the University of Melbourne.

The alumni are highly competent aerospace scientists who are capable of making distinguished and vital contributions both to their disciplines and to society. The School could have no fitter testimony to the success of its objectives and its programs.

ENGINEERING PHYSICS

When first introduced in the University's 1946 Announcement, the undergraduate engineering physics program was said to provide "a type of education and training which will effectively bridge the gap between the basic sciences and engineering. . . . Its general aim is to prepare students for careers in technical research and advanced engineering development." It was further stated in the Announcement that, "the course of study is designed to combine the broad, basic scientific and analytical training of the physicist with the knowledge of the properties of materials and the technological principles of the engineer."

The following examples of positions held today by Cornell engineering physics alumni are a good indication that these objectives have often been realized:

the manager of the Aerospace Sciences Laboratory of Lockheed Aircraft

a senior research physicist at the General Electric Research Laboratory

a research astronomer at Mount Wilson and Palomar Observatories

the director of the science and technology task force for the President's National Crime Commission

a senior research surgeon for the United States Public Health Service

a lawyer with the "safeguard system" (which is intended to reduce the possibility of nuclear weapons proliferation) of the International Atomic Energy Commission (Austria)

the director of the Arecibo Ionospheric Observatory (Puerto Rico)

the manager of the Battlefield Weapons Systems Laboratory at Hughes Aircraft

the supervisor of the mathematical applications group in Procter and Gamble's engineering division

the curator of the division of electricity, Smithsonian Institution

the president of Gourdine Systems, Inc., a company engaged in direct energy conversion products

a professor of applied physics at Stanford University, who is teaching solid state theory

In addition to directing the undergraduate engineering physics program, the faculty of the department maintains the graduate degree programs of Applied Physics and of Nuclear Science and Engineering. The first Master of Science degree was awarded in Applied Physics in 1948, the first Ph.D. degree in 1952. Since 1946, eighty-nine Master's and forty-three Ph.D.'s have been awarded. Two years after the dedication of Cornell's Nuclear Reactor Laboratory in 1961, both Master's and doctorates were awarded in Nuclear Science and Engineering, with a total, to date, of six Master's and nine Ph.D.'s.

About seventy-five percent of recipients of the engineering physics baccalaureate have gone on to graduate study. Of these, most entered a graduate program in science, applied science, or engineering; seven percent of the graduates entered law, divinity, or business administration (See Table 1).

Since the first graduating class in 1951, about sixty percent of those Cornell engineering physics alumni who went on to graduate work did so in five schools: Cornell, Massachusetts Institute of Technology, Stanford, Harvard, and the California Institute of Technology. Between them, these graduates have won seventy-four major fellowships, including thirty-six from the National Science Foundation, twelve from the Atomic Energy Commission, seven from the National Defense Education Act, six from the National Aeronautics and Space Administration, three Fulbrights, and three Guggenheims.

A survey of the type of employment taken up by Cornell engineering physics undergraduate alumni was made last spring in conjunction with the Twentieth Anniversary Program. The distribution



Professor John Silcox (right) discusses some of the equipment in a laboratory in Clark Hall with a group of alumni touring the building.

below represents the response from about two-thirds of the alumni, excluding those now enrolled in a graduate school:

Employment	Number
Industrial research and development	66
Industry	18
National laboratories, foundations	14
Government agencies	5
University, college faculty	30
Medicine	4
Law	4

The effects on alumni employment of the engineering physics program can also be measured by comparing responses from the Cornell survey with those from another survey, The National Engineers' Register. Below is a comparison by type of employer and by type of work done.

EMPLOYER	Engineering Physics Graduates	National Engineers' Register
Industry or self-employed	63%	71%
Government	13%	15%
Education	21%	6%
WORK FUNCTION		
Research and development	45%	27%*
Teaching	21%	4%

*(6% research and 21% development or design)

Compared to other engineering programs at Cornell and elsewhere, a much higher proportion of engineering physics alumni have gone on to further study, particularly at the Ph.D. level. Of these, the majority have pursued studies in the newer, innovative fields of engineering and applied science: applied physics, aerospace engineering, nuclear science and engineering, applied math, and solid state physics. Such a response to the challenges of today's new sciences reflects credit not only on the graduates themselves, but on the faculty, and on the founding spirit of twenty years ago.

TABLE 1

Fields of Graduate Study	Number of Students
applied physics	44
solid state physics	20
high energy physics	8
theoretical physics	12
geophysics, meteorology, etc.	5
aerospace engineering	30
astronomy	7
plasma physics	4
nuclear science and engineering	25
applied math	22
systems (electrical engineering)	8
communications (electrical engineering)	13
mechanics and mechanical engineering	4
materials science	4
information theory/operations research	7
business administration	6
medicine	5
law	4
biophysics	3
divinity	2
economics	2
other	2

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