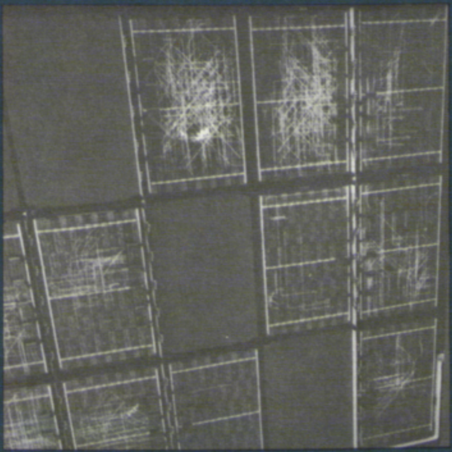
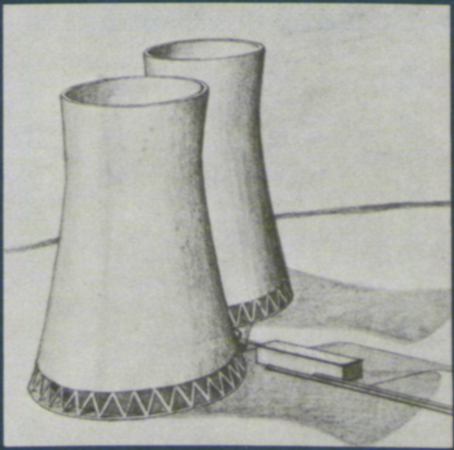
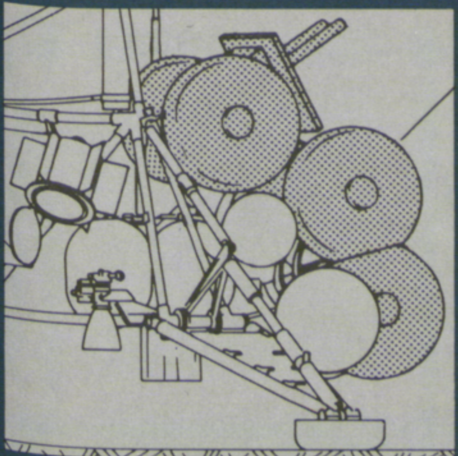
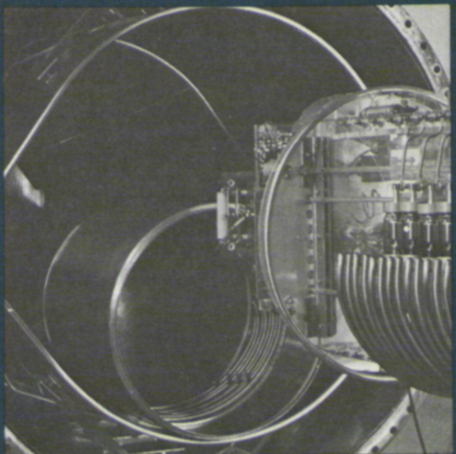
ENGINEERING

CORNELL QUARTERLY



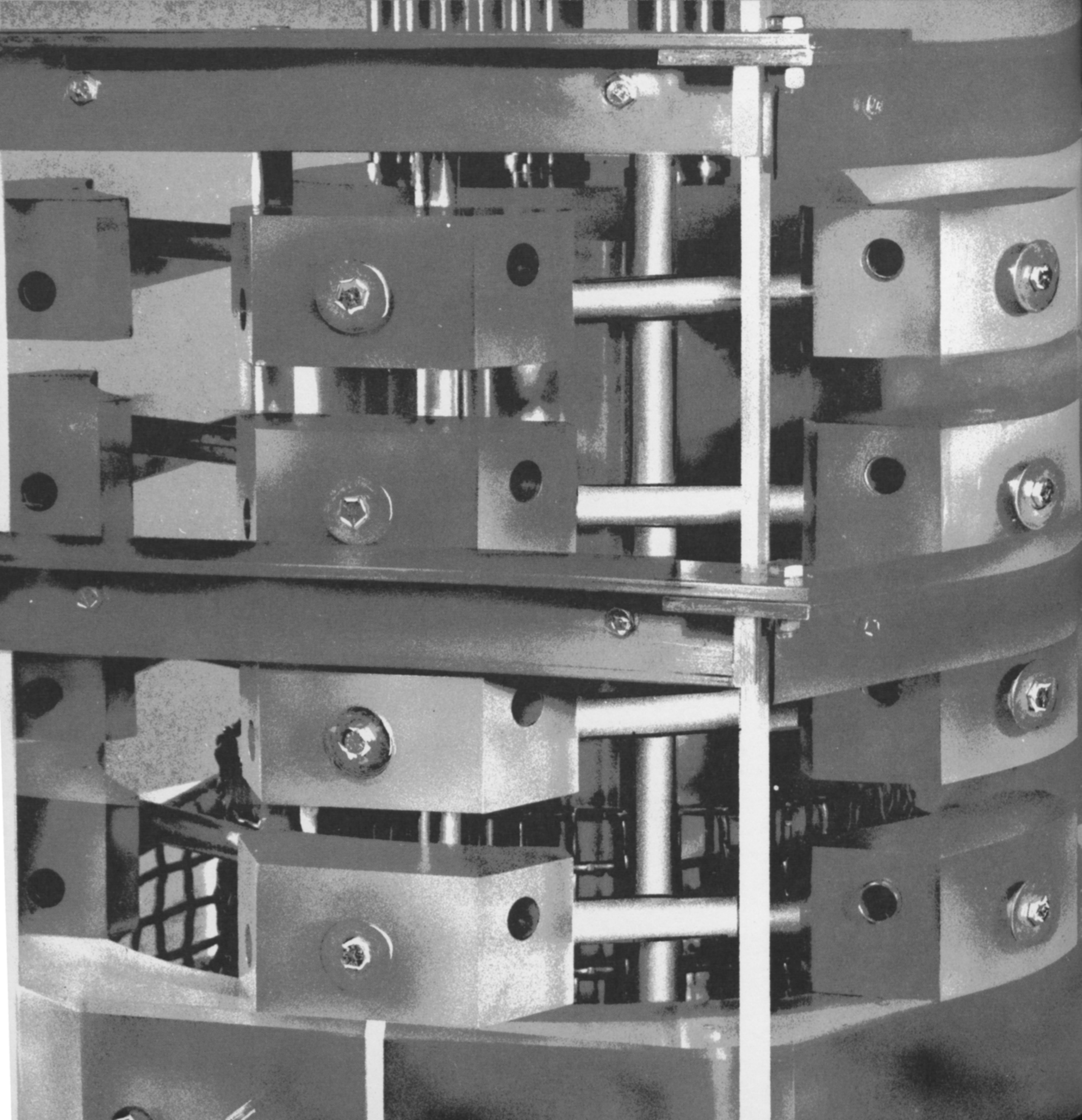






VOLUME 2
SUMMER 1967

TEACHING ENGINEERING DESIGN



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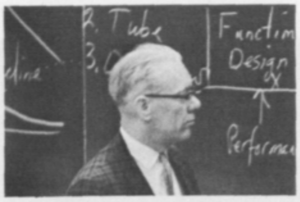

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Opposite: The design model for a prestressed concrete nuclear reactor vessel being developed by Professor Richard N. White, civil engineering.

STATE-OF-THE-ART

An Introduction by Donald F. Berth

A. M. Wellington, noted railroad construction engineer of the post-Civil War period, made two remarks that are highly pertinent to what engineers do today: "Anyone can plan a complicated mechanism; it takes an engineer to design a simple one," and [engineering is the] "art of doing well with one dollar what any bungler can do with two."

These still-apt remarks show that design was engineering's center of gravity in Wellington's time as much as it is now. There is, however, one major difference. The practice of engineering then was simpler. The underlying principles in science, applied science, and mathematics that had to be mastered in order to produce sound engineering solutions were fewer. Also, technological change was much slower. Most engineers who graduated from college prior to World War II left with knowledge and skills that could be applied at once, and that, for the majority of them, were sufficient for most of their professional lives.

In this period, design education was more classical. Technologies did not change overnight and the growth of knowledge was more modest, thus it was not only easier to teach current design, but one could be reasonably certain that such education would remain relevant for years. Such is not the case today.

The growth of the sciences and the resulting proliferation of new technologies have required a shift from applied to more fundamental studies. The graduate now approaches his first job armed with basic knowledge which is less likely to obsolesce. With experience, he learns to apply this knowledge.

Today, the search for effective design instruction methods requires not only a knowledge of the "state-of-the-art" but keen insight into what it may be in the years ahead. The processes of design—definition, analysis, search for alternatives, solution—have endured. Their complexity has increased. Analytical work, for example, is done with much greater sophistication and accuracy than before. But, because the engineering processes increase in complexity so rapidly, it is difficult for teachers of design to anticipate the future professional needs of their students.

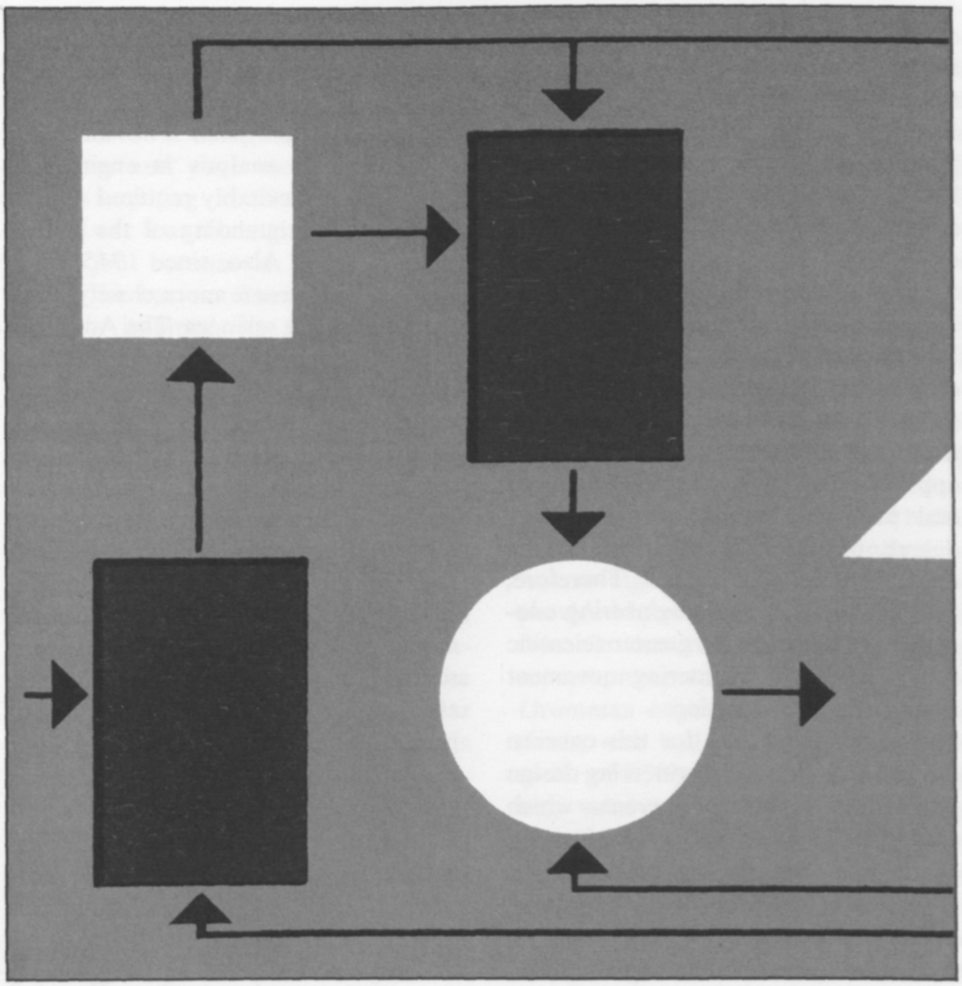
The importance of research in engineering colleges has often overshadowed effective design education. Research gives the faculty a solid grasp of the building blocks of tomorrow's engineering. Yet, it is in the art of putting these blocks together—design—that the mission of engineering lies.

In 1964, Cornell's College of Engineering set out to revitalize its program in professional education. Realizing that the content of undergraduate education has become mostly preprofessional, the faculty decided that a major thrust was required to build a strong professional identity on the graduate level. This meant establishing a degree program with objectives clearly different from the well-established Master of Science and Ph.D. research programs. Professional Master of Engineering degree curricula were established in connection with the seven undergraduate fields in the College as well as with the graduate areas of aerospace engineering, and nuclear science and engineering. In an extra, or fifth year of study, the candidate can obtain his degree through course work and a design project instead of a thesis. One sign of the success of this program is that Cornell awarded over 150 Master of Engineering degrees in June, 1967.

This issue examines a few of the imaginative approaches to design education being taken at Cornell. To begin, we present an informal discussion of the "State-of-the-Art" with Byron W. Saunders, Professor of Industrial Engineering, and Howard N. McManus, Professor of Mechanical Engineering. Both men chaired faculty committees that were charged by Dean Andrew Schultz, Jr., to "formulate the engineering practice and design objectives of the College of Engineering and point the way toward effective realization of these objectives." Their remarks place design and design education in historical perspective.

Alexander W. Luce, Visiting Professor of Machine Design, describes a design project course in Cornell's Sibley School of Mechanical Engineering. In it, students learned to consider alternatives in definition and solution of actual problems and to "design" solutions. Robert L. Wehe, associate professor of mechanical engineering, reports on a lunar rover which is being designed, built, and tested by Cornell students under terms of a $70,000 NASA contract.

Though this issue reviews only a few current design education projects, it reflects Cornell's strong interest in the professional engineer and in design.



STATE-OF-THE-ART

An Interview with Professor Howard N. McManus and Professor Byron W. Saunders

There seems to be much concern today as to how engineering design is being taught to engineering students. Why?

Saunders: To answer that I think we have to look at what happened in American education after the launching of Sputnik. Since then the concern for the scientific posture of our country has enhanced the importance of science in the educational process. Engineering educators of today turn their attention more to the underlying sciences than to their application. Design involves the application of science to the solving of real problems and for this a greater degree of scientific sophistication is required than ever before. Therefore, the direction taken in engineering education has been toward greater scientific content without a countering movement toward design instruction.

McManus: The cause for this concern about the teaching of engineering design goes back, I think, to events which took place long before Sputnik. I would characterize the years prior to World War II as a "build 'em" and "bust 'em" era in the practice of engineering in the United States. Following that war, a much greater emphasis was placed on analysis, partly because of the development of high-performance devices during the war years. The increased importance of analysis in engineering practice has inevitably required a more thorough understanding of the underlying sciences. Also, since 1945, engineering has become more closely allied to the emerging sciences. The American strength in design education declined and now we need to emphasize design instruction in order to restore the balance.

Well, how does design fit then into the overall scheme of things in engineering education?

Saunders: Let me define engineering design as being that process in which science is applied with judgment to satisfy some useful human purpose. If problems which are important to some person or group of persons are being solved by an engineer, then he is performing the function of design.

McManus: Many laymen and some engineers and managers tend to feel that design is analogous to sketching or drawing an object. In engineering design, there are many engineers who never draw "pictures." Most of my efforts as a working engineer were in the area of analysis. Often, my work had bearing on a final design and, in some cases, radically changed the tentative conclusions that had been formed on the best way to solve a specific design problem. Design as an engineering function needs to be viewed by educators in a much broader light than is now being done.

Saunders: Well, I wouldn't disagree with that. Certainly analysis is a very large and necessary part of the design process but an analyst may make analyses of the alternatives without concern for the total problem. Design involves a creative process as well as a consideration of the possible solutions to a particular problem.

Could each of you give us an example of a design problem which might be encountered in your own professional field?

Saunders: Suppose a small job shop has a serious problem in its dispatching of work which causes many delays and much customer dissatisfaction. Suppose

Howard N. McManus

Byron W. Saunders

some engineer looks at the problem, then says to management, “Well, there isn’t anything we can do because you have to use a computer to solve your problem and your men don’t understand anything about computers.” I would say that the engineer has done a poor job because a problem exists which he has not been able to solve. In this instance, he is suggesting a technology which is inappropriate to their needs or a technology which is needed but, at the moment, is too advanced for the personnel. While our engineer may be capable of designing a very sophisticated information system involving the latest techniques and equipment in high-speed computation, the job shop may lack the funds to purchase such equipment. The matching of the level of technology to the needs and capacities of a particular activity in an optimal manner, then, is an illustration of an industrial engineering design problem.

McManus: Some of the problems that were posed to our professional Master’s candidates in mechanical engineering last spring may be illustrative of engineering design problems in which the emphasis is on analysis. One such problem, proposed by Grumman Aircraft, had to do with the design of a radiation system for expelling heat generated in a space capsule. Heat discharges, ranging from 2,000 BTU’s per hour maximum loading to a minimum of something on the order of 600 BTU’s per hour, had to be “dumped.” Using a specified type of circulatory fluid, a system had to be designed which could perform within the desired limits.

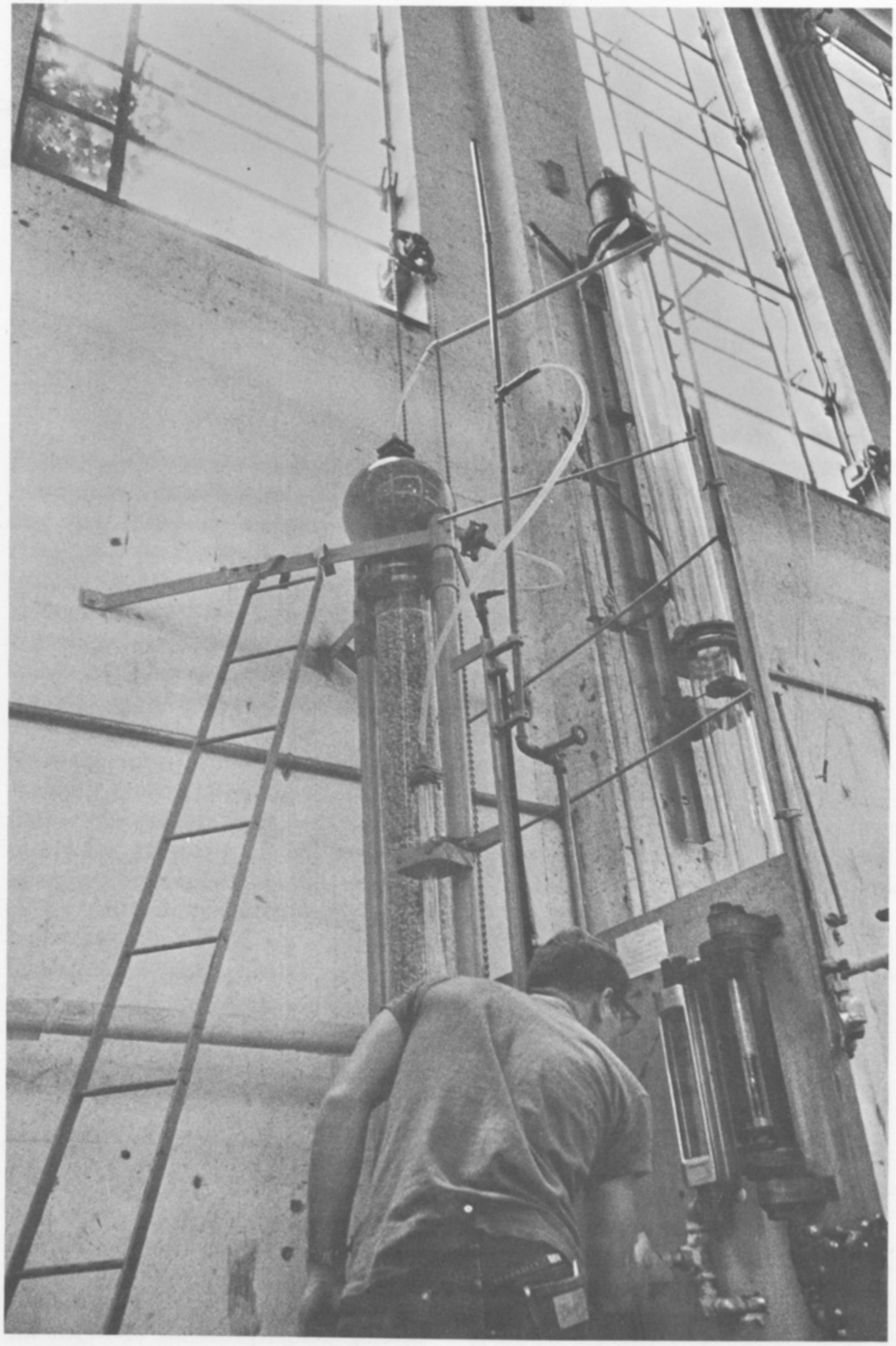
The students carried out the engineering problem, ultimately coming up with a design scheme that was based on their analysis. Because the cost of building a model to test their conclusions was so high, we relied on the critique provided by engineering representatives from Grumman. In their review of the report presented by our students, the Grumman engineers said that the students, who had put something on the order of 350 man-hours into the project, were well on their way toward arriving at a design which had every promise of working. Years ago with limited analysis, a variety of prototypes would have been tested until the desired design conditions were found.

You suggested the limits of the problem in terms of BTU's. Were costs also a major consideration in arriving at an appropriate design?

McManus: No, in the aerospace industry the critical problems are more often excessive weight and reliability than cost. Dollars are much more a limiting factor in design problems for, say, the automotive industry than they would be for the aerospace industry.

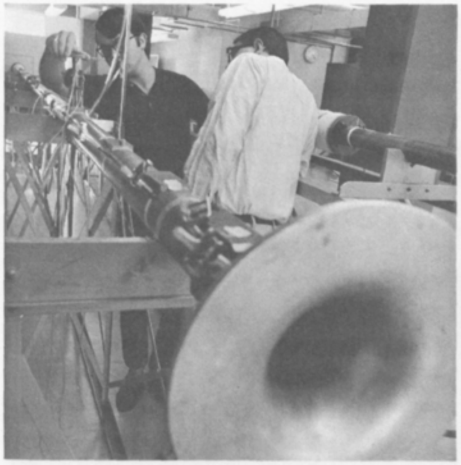
We know there are great differences in what is designed in the various engineering fields. However, are there any common bench marks that can be applied to the function of design, regardless of the field?

Saunders: I would say so. The adjectives "electrical," "mechanical," "industrial," "civil," merely describe particular types of engineering. The basic design processes are the same among the several fields. Once an engineer has properly defined the problem, he must then proceed to go through a creative process which takes into account all possible alternatives. Their evaluation may be colored in one instance by a critical weight requirement as was the case



Opposite: A chemical engineering student adjusts the flow rate to a packed absorption column in the unit operations laboratory. Later in his program he will be expected to design a chemical plant.

Below: As part of their laboratory work in thermal engineering, two mechanical engineering students are studying velocity profile patterns as they vary the rate from the laminar to the turbulent range.



in the heat radiator example given by Professor McManus, or there may be critical dimensional or cost requirements. Perhaps the engineer is working with a processing problem and must consider various material processing alternatives such as electrochemical action, chip removal techniques, forging, or extrusion of the material. But, although the overriding criteria upon which the ultimate design is to be measured will vary considerably from problem to problem, and from field to field, the essential process is the same.

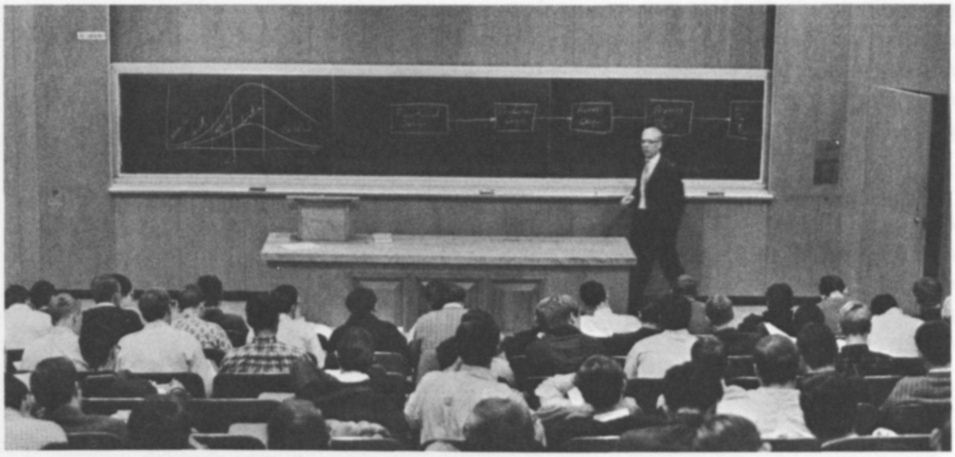
McManus: Your question brought to my mind a particular pedagogical school of thought in which design problems are approached through a series of well-defined steps. The use of "road maps," if you will, can provide the student with such a crutch that the personal creativity, which we hope to spark in him through the design "experience," can be quickly extinguished.

At Cornell, each of you has chaired a committee dealing with the problems of design education. Could you give us a brief rundown of the manner in which design education is approached in the various fields?

McManus: All of the major disciplines are involved in the teaching of design in one way or another. The School of Electrical Engineering has a laboratory sequence, beginning in the junior year, in which a significant portion of the total time is devoted to design. The intent of the faculty of the School of Chemical Engineering is to emphasize design experimentally and analytically, and, in fact, students there actually worked on the design of chemical process plants. Because of the nature of the field, civil engineering, which is concerned with large, frequently one-of-a-kind structures, emphasizes design analysis. In mechanical engineering, we bring the teaching of design into the laboratory as well as into the classroom. Our students' projects are open-ended, typical of those that engineers increasingly face in professional practice today.

Saunders: In industrial engineering, we have for many years been dealing with real problems obtained from industry, and we try to solve them in our curricular program. We ask industry to give us considerable latitude as to what information is available to our students; that is, we try to provide problems whose limits are not too explicit. Sometimes we are concerned only with definition of the problem which itself can involve considerable analysis. Often in the process of definition we find that what was thought to be the problem is not and we have not one but several problems to solve.

McManus: In some other disciplines, design problems are frequently more specifically stated than those explored by industrial engineering students. But



always when choosing the problems we must consider whether they are worthwhile teaching tools in view of the limited amount of time available for student design projects.

Would you say that design instruction in engineering colleges today is more effective than it was, say, in 1950?

McManus: I don't think a "yes" or a "no" answer is possible. When comparing engineering education at two points in time one has to be very careful to remind oneself that there has been an almost radical change in engineering practice. The teaching of design in 1950 might have been very appropriate for the needs of that time. The demands made on today's engineering graduate are different, and educators are moving more rapidly in those directions that will prepare their students for the type of engineering they will encounter in the future.

Saunders: I will answer "yes" to your question because today there is a much better basis upon which to develop skill in the analytic aspects of design than there was fifteen or twenty years ago.

What about the accusation that industrialists so frequently make, that colleges and universities aren't turning out engineers any more?

Saunders: Often a man who expresses this point of view is thinking in terms of an engineering education that he himself experienced or understood. Then too, practicing engineers often think of engineering in terms of what their needs have been in the past rather than with some thoughtful reflection as to what they might be in the future.

McManus: Frankly, most engineering students are considerably overtrained for many of the industries in the United States. It must be particularly disconcerting to managers and supervisors to be confronted with engineers who approach problems quite differently from how they themselves would. Perhaps today's engineering graduate is not immediately as productive as were his father and grandfather, but he is better equipped to grow and develop in his profession. His broader training will contribute to the improvement of engineering in his industry.

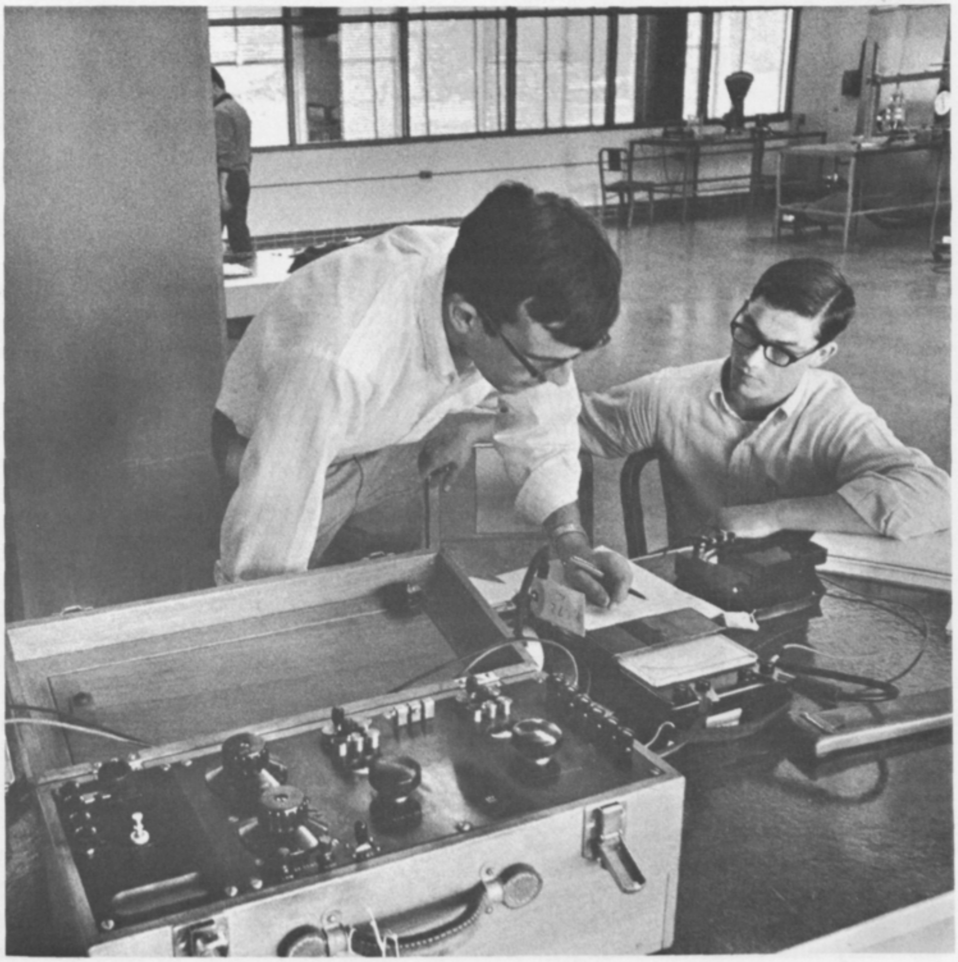
More and more engineers join the teaching ranks immediately after graduation. Does their having had little or no exposure to the "real world" of engineering have any effect on their ability to teach engineering design?

Saunders: Realizing that it takes many skills to do good engineering design, I see no need to be concerned about the fact that some teachers of engineering have never had industrial experience. True, they may lack an appreciation for those "right" decisions that are made on the basis of experience. But to say that all engineering teachers should have such an exposure is, I feel, asking too much. The important thing is to have a faculty with overall "balance."

McManus: There are several avenues now open that allow young teachers who want it to gain some professional experience in industry. The Ford Foundation, for example, supports selected professors for periods of work in industry so that they can gain greater insight into contemporary engineering practice. We're also finding companies that are interested in and willing to support young faculty members who want to

Opposite: Professor Byron W. Saunders lectures to industrial engineering students in an introductory course that relates the science of operations and the engineering of complex man-machine systems to design methodology.

Below: For electrical engineering students, a four-term laboratory sequence is used to demonstrate how developments in electrical engineering practice result from a blending of theory and experimentation. Here students work on basic measuring equipment that involves circuits and fields of both active and passive elements.



work with them either during a summer period or for a year while on leave from their college.

Saunders: There is another point that needs to be mentioned here. Any young man embarking upon an academic career must consider how he can best earn tenure. The ways to do this are limited. Traditionally, to assess the potential intellectual vigor of a candidate, his performance in research is evaluated. It is much easier to assess his ability to tackle problems in unknown areas, to produce reasonable results, and to report them to his peers than to evaluate his skill at solving engineering problems in industry or with students in a classroom. Therefore, the younger man tends to avoid industrial experience, especially during his early years.

McManus: Let me add a bit. A faculty member's effectiveness in research is judged by his ability to attract research support and his ability to publish his findings. Generally, his work has to pass through boards of review: first, the research proposals themselves are reviewed and then the published articles. In design, such mechanisms do not exist. Only very recently has bona fide support been obtained for work in engineering design. Furthermore, reports of specific solutions to design problems are generally not received with much enthusiasm by engineering publications. I can understand the reasons for this. Publication costs are high, there is a large volume of literature produced, and the subject may not be of interest to a broad group of people. In the Committee on Engineering Design which I chaired, we recommended the development of a design journal. But at present it isn't feasible to evaluate a man's merits in design on the basis of his publications.

Can engineering design problems be introduced as early as the freshman year?

McManus: My own experience with freshmen suggests that while they are interested in engineering problems, they are not really capable of handling anything that requires much depth. They deal best with problems of definition. There, they have to consider what factors should be examined to solve a particular engineering problem. Even at that, we have had several interesting violations of the first law of thermodynamics!

Thinking over the years that I have been in engineering teaching, the attitude of engineering students has shown a remarkable shift. Fifteen years ago a freshman entered mechanical engineering generally because he was interested in machinery or power; today's freshman is not likely to have interests like those. So, if we are going to arouse their interest in engineering design, we have to consider carefully what kinds of subject matter will most appeal to them.

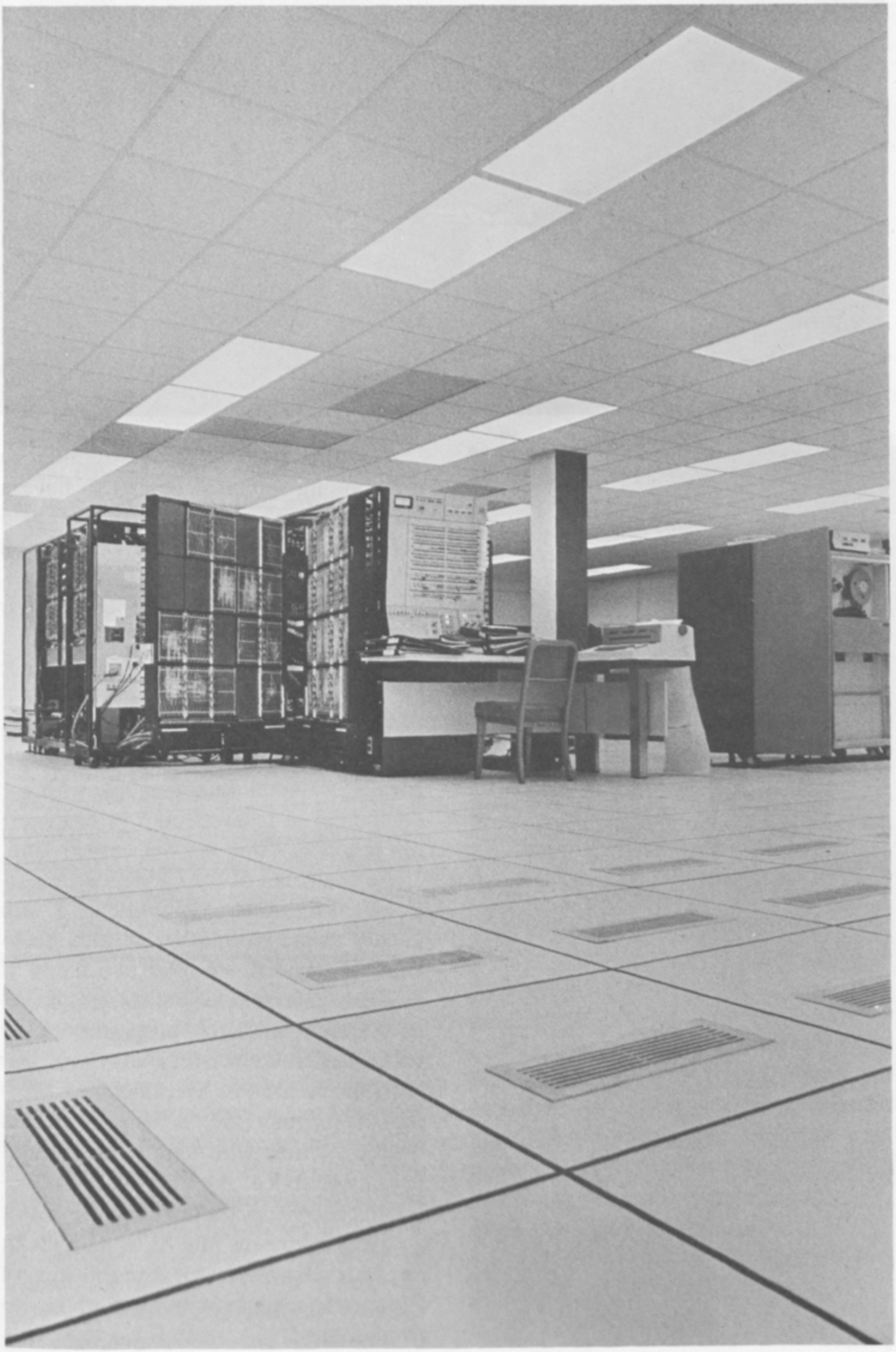
It has been said that the engineering problems of tomorrow are bound to be more interdisciplinary than they have been in the past. What are the implications of this for design education?

Saunders: It is certainly true that there is a greater intermixing of disciplines today than there has ever been in the past and the trend is likely to continue to an even greater extent. For example, electrical engineers will undoubtedly deal with more problems of a mechanical nature, such as heat transfer, than they formerly did. New fields are constantly emerging and today's graduate will likely find himself working in an area of engineering that doesn't even exist today. Our educational programs in engineering need to be planned with these facts in mind so that we can prepare graduates who can function in this manner.

McManus: Whether we will ever get to the point where there would be a field of "interdisciplinary engineering" I don't know. I think we must remind ourselves that an industry is normally centered around one or two technologies, although the technologies may apply to other industries as well.

The Cornell engineering students who enroll in our Engineering Cooperative Program seem to be more enthusiastic about their course work after their experience in industry. Why is this?

Saunders: The program gives them a chance to see "in the flesh" some of the constraints that are of concern to engineers. A professor can talk about them in the classroom but the words are empty until the student has to contend with such constraints himself. The engineering student who has had a really meaningful work experience in industry can tie together what he is learning in the classroom and in the field and can



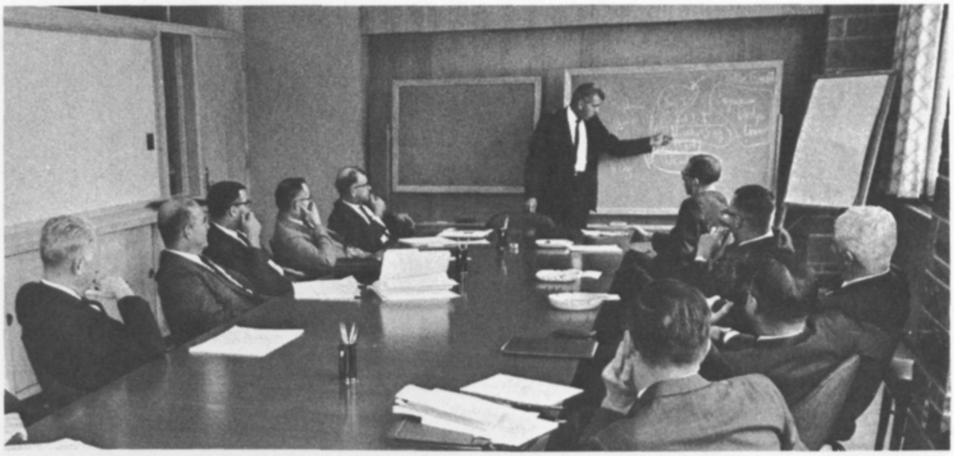
A powerful tool in design analysis, high speed computation has changed many steps in engineering design from an art to a science. Currently being installed at Cornell University's Langmuir Laboratory is the new IBM 360/65.

see the relevance of his education to the whole process of becoming a professional engineer.

McManus: I would emphasize Professor Saunders' last point, that is, relating what is taught to the real world. A brief professional experience can stimulate the student's interest in education for he can see where his classwork fits into the overall scheme of things. I think we all feel more interest when we see the relevance of what we are doing.

In an effort to promote better engineering design instruction, what areas do you think need further attention here at Cornell?

McManus: In mechanical engineering, we hope to extend industrial cooperation in our engineering design program. Several excellent problems were furnished to us this past year by Carrier Corporation, Grumman Aircraft, Taylor Instruments, and the New York State Electric & Gas Corporation. General Dynamics furnished some problems for electrical engineering students. These industries have on occasion sent their engineers to Ithaca and, when necessary, students have visited them. We seek more such cooperation.



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We also need to give attention to maintaining sufficient faculty to have a viable design program. As we said before, most young faculty members have had little industrial experience, and there is not much chance of their getting it while they are striving to get tenure at the University. Industry is not an ideal source of engineering design faculty because industry tends toward specialization while we require breadth. Ideally, we should have people who are competent in research and in engineering practice. They are not easy to find.

As chairman of the Graduate Professional Programs Committee, I am keenly aware of another serious problem. At Cornell, we offer two kinds of graduate programs. The Master of Science and Ph.D. degree programs are the traditional route for men who want careers in research or teaching. The Master of Engineering is a professional degree for men who want to enter engineering practice. At least there is adequate fellowship support for the better students who seek the M.S. and Ph.D. degrees. However, for the Master of Engineering candidates support is, indeed, limited.

1. Informally discussing their research progress with Professor Richard Phelan, left, and Professor Howard McManus, are three of the four NASA fellows who are working for their Ph.D.'s in mechanical engineering design.
2. Periodically, faculty members from Rensselaer Polytechnic Institute and Cornell's College of Engineering meet to explore individual and joint methods of improving design education. This work is partially funded by a grant from the General Electric Educational Foundation.

Saunders: Agreed. Support for professional education has always been modest in comparison to that given to programs whose major objective is to develop research competence. Because of this, students frequently pursue graduate programs that are not designed explicitly for their real interests. Because of financial need, many select those programs with the best financial support that come closest to their interest. This is of serious concern for, unless there is greater financial support, it is going to be very difficult to strengthen professional education. In this, industry could aid greatly.

Howard N. McManus of the Sibley School of Mechanical Engineering has had a varied career in teaching and in industry. After obtaining the Bachelor's and the Master's degrees in Mechanical Engineering from the State University of Iowa, he received the Doctor of Philosophy degree at the University of Minnesota where he was an instructor. Subsequently he was an assistant professor at Northwestern University; then in 1957 he joined the faculty of Cornell University where he is now a full professor.

Since 1950, Professor McManus has spent nearly every summer working in industry or pursuing government-sponsored research. Among these affiliations have been the United States Naval Ordnance Laboratory; Chance Vought Aircraft; Westinghouse Electric Corporation; United States Army Signal Corps Research, the University of Minnesota; General Mills; and Pratt & Whitney Aircraft. In addition, he has been the principal investigator for several projects, sponsored by the Office of Ordnance Research, by the National Science Foundation, and by the Cornell Aeronautical Laboratory.

At Cornell, Professor McManus has chaired numerous committees, among them the Graduate Professional Programs Committee, the Engineering Faculty Committee on Engineering Design, and the Physical Sciences Area Committee of the Graduate Fellowship Board.

He is a member of Tau Beta Pi, Sigma Xi, Pi Tau Sigma, Phi Kappa Phi, and the American Society of Mechanical Engineers.

Byron W. Saunders, Professor of Industrial Engineering and Operations Research and Director of that School, obtained his Bachelor of Science in Electrical Engineering degree from the University of Rhode Island and his Master of Science in Engineering Economics from Stevens Institute of Technology.

After receiving the Bachelor's degree, Professor Saunders was employed by the Narragansett Electric Company for one year as a student engineer. Thereafter he became the electronics engineer for the Douglas H. Paton Company, then became manufacturing development engineer and assistant manager for plant engineering for the Radio Corporation of America where he remained from 1940 to 1947 when he joined the Cornell faculty.

Professor Saunders has done consulting work for the Western Electric Company, the General Electric Company, the Pleasant Valley Wine Company, and the Lamson Corporation.

In 1960–61, he held the Joseph Lucas Visiting Professorship at the University of Birmingham in England.

Professor Saunders is active in several professional societies and is a member of the American Institute of Industrial Engineers, the American Society of Mechanical Engineers, the American Association of University Professors, and the American Association for the Advancement of Science. At present, he is chairman of the Industrial Engineering Division of the American Society for Engineering Education.

STUDENTS DESIGN LUNAR ROVER COMPONENTS

By Robert L. Wehe

Before an engineering student's education can be complete, he should be placed in situations where he must use the totality of his knowledge, judgment, and experience. Without such learning situations, he is likely to leave college with an educational background made up of disparate parts. Therefore, for the sake of both science and engineering, engineering education must try to produce graduates who do not endlessly stockpile knowledge, but who use it and at the same time maintain an interest in the underlying sciences and in research. This means we must produce engineers who can design.

Design is a term applied to engineering activities that range from almost fool-proof procedures for determining the dimensions of simple machine parts to the planning of national traffic systems. It is a term which has defied definition although Professors Allen B. Rosenstein and Morris Asimow of U.C.L.A. have given a general idea of what is meant: Engineering design is "an iterative decision-making process" and "a purposeful activity directed toward the goal of fulfilling human needs, particularly those which can be met by the technological factors of our society."

Engineering design is not new at Cornell. In their research activities, many professors have been involved in it. Students, too, have worked on design projects, some of which have been patented. What is new is the attempt to provide more extensive projects requiring design teamwork by students with varied technical backgrounds. The emphasis now being placed on design education is aimed at restoring the balance between science and technology.

In the interest of furthering design instruction, Cornell has secured a NASA-funded contract for specific student-designed hardware. This situation is unusual because the students are producing usable goods, not just theoretical solutions on paper. Contract support was desired by both Cornell and NASA. The sponsoring faculty members felt that the most vital design situation is one which is bounded by time, financial resources, and contract specifications, all of which are difficult to simulate without a contract, and NASA officials believed that a contract situation is good training for students who will one day work under similar circumstances for government or industry. Working in a program parallel to Cornell's is Rensselaer Polytechnic Institute. Rensselaer proposed to design a landing gear and remote control system for a Mars vehicle while Cornell proposed to design, develop, and test components of a total control system for a lunar-roving vehicle.

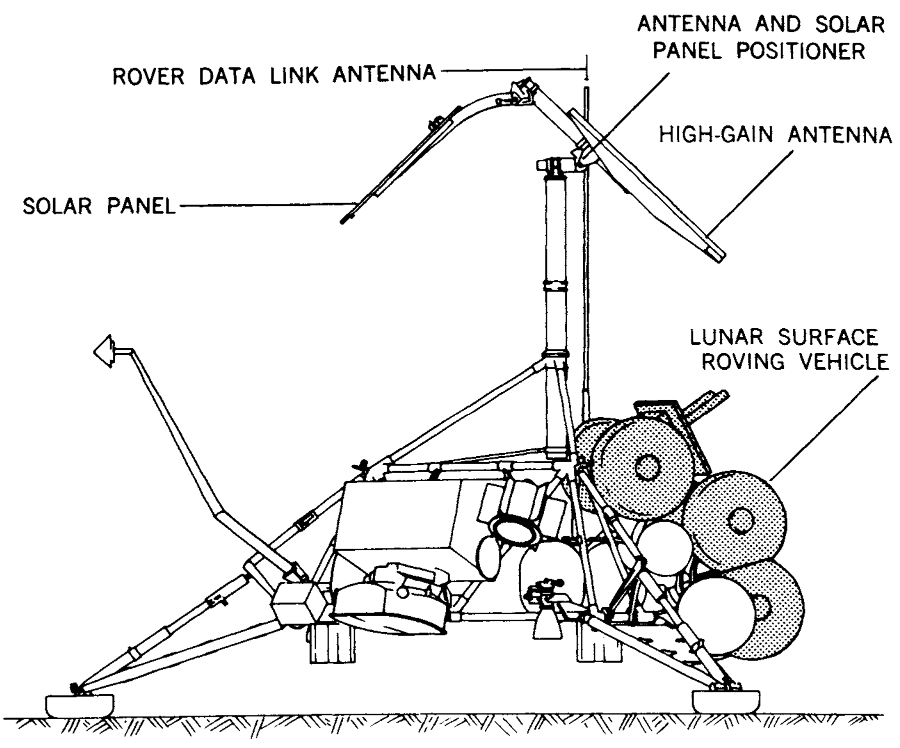
THE PROBLEM

The exploration of a portion of the moon's surface by an unmanned roving vehicle is a logical step in the program of manned lunar exploration. The unmanned vehicle must accomplish a traverse and report its findings to earth stations either directly or through a stationary relay module. The control system for such a roving vehicle is the subject of Cornell's proposed design investigation.

Certain problems are immediately apparent in designing a vehicle that is to rove untethered on the moon. If it lands on the lunar surface in workable condition and correctly oriented, the vehicle should be ready to begin exploration. The terrain of the moon in the region to be explored will be known in some detail beforehand. Should the path be clear, the vehicle, containing a homing device, could explore and then return to base over much the same path. However, it is doubtful that a path entirely free of obstacles can be found. If there are obstacles, the vehicle's control system must contain a decision-making device that will enable it to adjust its paths at need in exploration and in return. One means of obstacle detection might be to use an earth-based or orbiting human operator who could see obstacles via a television camera mounted on the vehicle. Other possibilities would be to use self-contained microwave radar, laser radar, or mechanical sensors.

A pictorial record of at least a sampling of the region traversed can be

Shown at the right is a Mariner satellite with lunar surface roving vehicle attached.



obtained either photographically or electronically. Television could be used for this purpose as well as for obstacle detection with the advantage that it would not add weight or require more power than that already needed for sending information back to earth.

In order to develop a system encompassing the above factors, Professor Wilbur E. Meserve of the School of Electrical Engineering and I are working half time on the project, and six Master of Engineering students are working full time during the summer and ten hours each week during the school year. Student response to the proposed project has been most impressive. Many applied for this work although they could have earned more in industry. The students were selected for the project on the basis of their application statements and their interviews.

The project year lasts from July 1, 1967 to July 1, 1968. By January 1, 1968, it is expected that the basic rover will be assembled and in working order, and that the time thereafter will be spent on obstacle-detection devices and controls. The budget for this project is $70,300 of which $20,000 has been allotted for construction costs.

The summer's work began with a briefing session by representatives of NASA: Pitt G. Thome, Manager, Advanced Programs of Technology of the Lunar and Planetary Programs Office; Michael R. Gill, Staff Engineer of the same office; and Robert Powell and Richard Morris of the Jet Propulsion Laboratory. Since then, the NASA representatives have visited Rensselaer and Cornell for review sessions each month.

The nature of the students' work and the implications of the total problem as a learning experience can best be understood by reviewing design progress to date.

TEST VEHICLE

The test vehicle needs to simulate a lunar vehicle only insofar as its behavior affects the action of the control systems to be tested. However, for a number of reasons, the vehicle will be similar to the General Motors Research (GMR) Corporation vehicle which the Cornell team decided would perform best on the moon. This vehicle consists of three carriages connected by a spring frame. Each carriage, rigidly attached to its axle, has two wheels that are driven individually by motor reducers. The vehicle is steered by turning the front and rear carriages. To help it negotiate obstacles and keep maximum contact with the ground, the vehicle's spring frame is very flexible in vertical bending and twist about the horizontal axis. The wheels of the Cornell rover will probably be different from those on the GMR vehicle because the student design team favors the spiral wheel developed by Grumman Aircraft. The vehicle will be completed and operating on Cornell's Engineering Quadrangle this fall.

MOTION CONTROL

The proposed motion control system is extremely simple: a single speed forward and one in reverse. The steering control will have only two or three positions in each direction. Even though the vehicle will have to follow a gyro-heading, the first design will provide an

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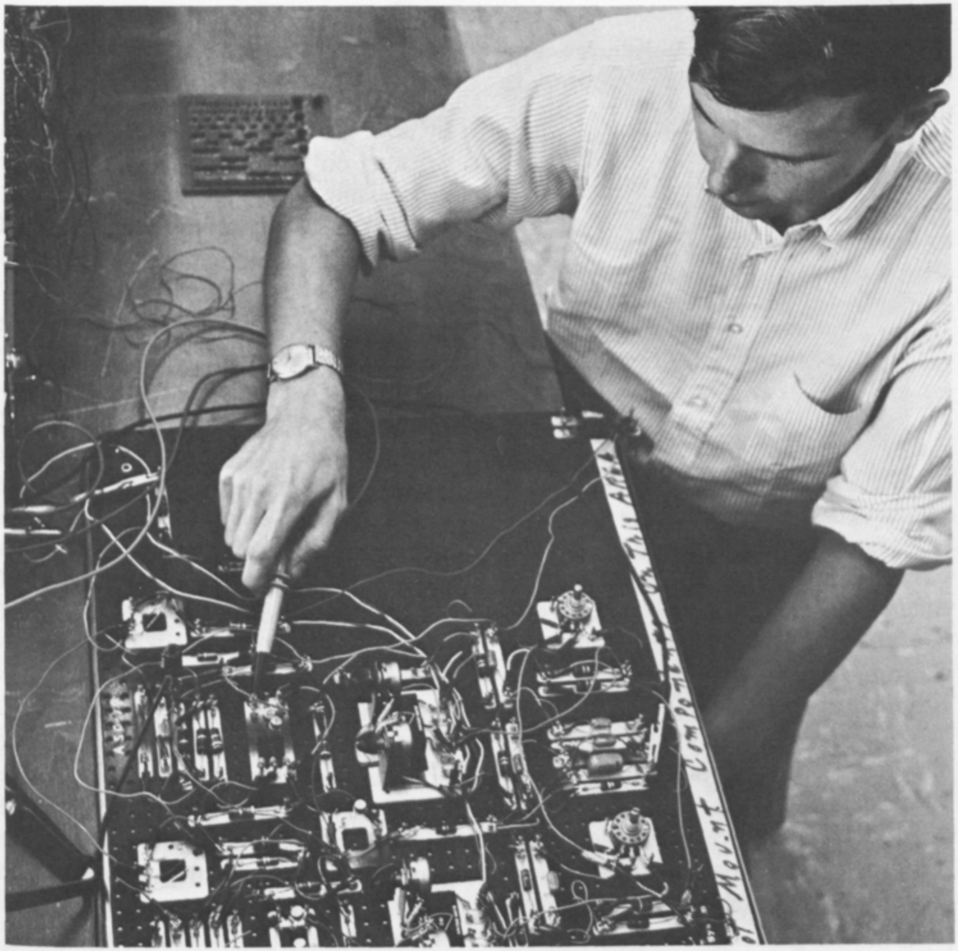


1. *A student tests his motion control prototype. The steering control will have only two or three positions forward and reverse.*
2. *The logic circuits that will code and decode the signals sent from the lunar rover to a station on earth are being tested by one of the project's student staff members.*
3. *A sensor will be required to keep any lunar rover from turning away from one obstacle and into another. Shown here is the preliminary testing of a laser sensor system.*

3

". . . the most vital design situation is one which is bounded by time, financial resources, and contract specifications . . ."

on-off control rather than a continuous-feedback control. If it succeeds, a considerable saving in power should be realized.

RADIO CONTROL

An unmanned lunar rover must respond to commands from earth as well as to commands from its own program and sensors. Commands will be sent to the test vehicle by means of radio control utilizing a hand-held citizen's band transceiver. The logic circuits that will code and decode the signals have been assembled on a breadboard and run through the desired operation. The final component is assembled but has yet to be operated.

ELECTROMECHANICAL OBSTACLES SENSOR

As an adjunct to the project, a graduate student in mechanical engineering who is interested in control is doing a thesis investigation on aspects of one type of obstacle sensor. He has built an operating model that will indicate to the vehicle's decision-making control the height and width of obstacles. The vehicle can negotiate obstacles up to thirty inches high. If the sensor indicates that they are higher, the vehicle must find another path. Similarly, the vehicle can negotiate crevasses of up to twenty-four inches wide; should the sensor show that a wider one has been encountered, a different path will be sought.

ELECTROMAGNETIC SENSOR

One member of the student design team has postulated a laser system which could sense not only obstacles too large to be negotiated that lie in the vehicle's path, but those that lie to either side of the path as well. If successful, this system will prevent the vehicle from turning away from one obstacle and into another.

Another possibility for obstacle detection is the use of high frequency microwaves in what may be called a radar device. Studying this possibility will probably be a project for some students in a Master of Engineering degree program.

SOIL SAMPLER

Samples of the lunar soil are desired by both the engineers and the scientists working on lunar exploration. Work is progressing on a device for the Cornell vehicle that will not only obtain and store soil samples but test the soil as well.

In a project such as this, there are no "right" answers. As the student works through the various design considerations weighing the advantages and disadvantages, he must recognize that whatever solution he has reached, the problem is still open-ended in that there are a multitude of factors with which he has not been able to cope because of limited time and money and a lack of personal knowledge of all the technologies involved. Through personal experience he learns that the constant refinement of techniques and advancement of technology threaten to make obsolete rapidly any design which is not planned with a maximum of foresight. If he leaves the project with a sense of the many technologies, systems, and social factors involved, if he sees the value of experience and of rational decision-making procedures, then we have produced a student of technology as well as a technologist, a student of decision theory as well as a decision maker.

Robert L. Wehe is an associate professor of mechanical engineering whose principal interest is engineering design. In this connection he has been active since 1954 in the Lubrication Division of the American Society of Mechanical Engineers (ASME), writing technical papers, compiling literature compendiums, and presenting state-of-the-art talks. He has held many Division posts, and two years ago served as its chairman.

At Cornell, Professor Wehe has developed and taught several courses and laboratories in systems design. He has served on numerous committees in the Sibley School of Mechanical Engineering and is, in addition, faculty adviser for the ASME student section. He is a past president of the Cornell chapter of Sigma Xi.

Professor Wehe earned the Bachelor of Science in Mechanical Engineering degree from the University of Kansas and the Master of Science in Engineering degree from the University of Illinois. His industrial experience includes a year as project engineer in the process development division of the Corning Glass Works; a summer program with the Westinghouse Electric Corporation; a year as supervisor at the Seneca Falls Machine Company; and six months on a special project with the Lycoming Division of Avco, in Williamsport, Pennsylvania. He does consulting work for the Cayuga Rock Salt Company and for local legal firms.

In addition to the organizations mentioned, Professor Wehe is a member of Tau Beta Pi, Pi Tau Sigma, and the American Society for Engineering Education.

DESIGN REALISM FOR THE CLASSROOM

By Alexander W. Luce

Teaching design today is difficult because the professional content of undergraduate engineering programs is dwindling. Since such basic preprofessional subjects as mathematics, science, engineering science, humanities, and social science consume the greater part of the undergraduate's time, most colleges of engineering must establish the entity of professional engineering during graduate study. At this stage, Cornell tries to simulate complex professional experience in the classroom so the graduate will not require so long an adaptation period on his first job.

In teaching design, we point out that engineers in professional practice *conceive* useful devices, processes, and structures and are concerned as well with how existing devices, processes, and structures can be *applied* to new problems. Combining *conception* with *application*, they *design* or plan programs and systems to fulfill human needs. This work is analytical in that they must determine the problem itself as well as the methods by which it will be solved. Design work is interdisciplinary, encompassing several fields of engineering and science. Finally, it is creative, requiring imagination and ingenuity to use already existing technology in more effective ways or to create new technologies.

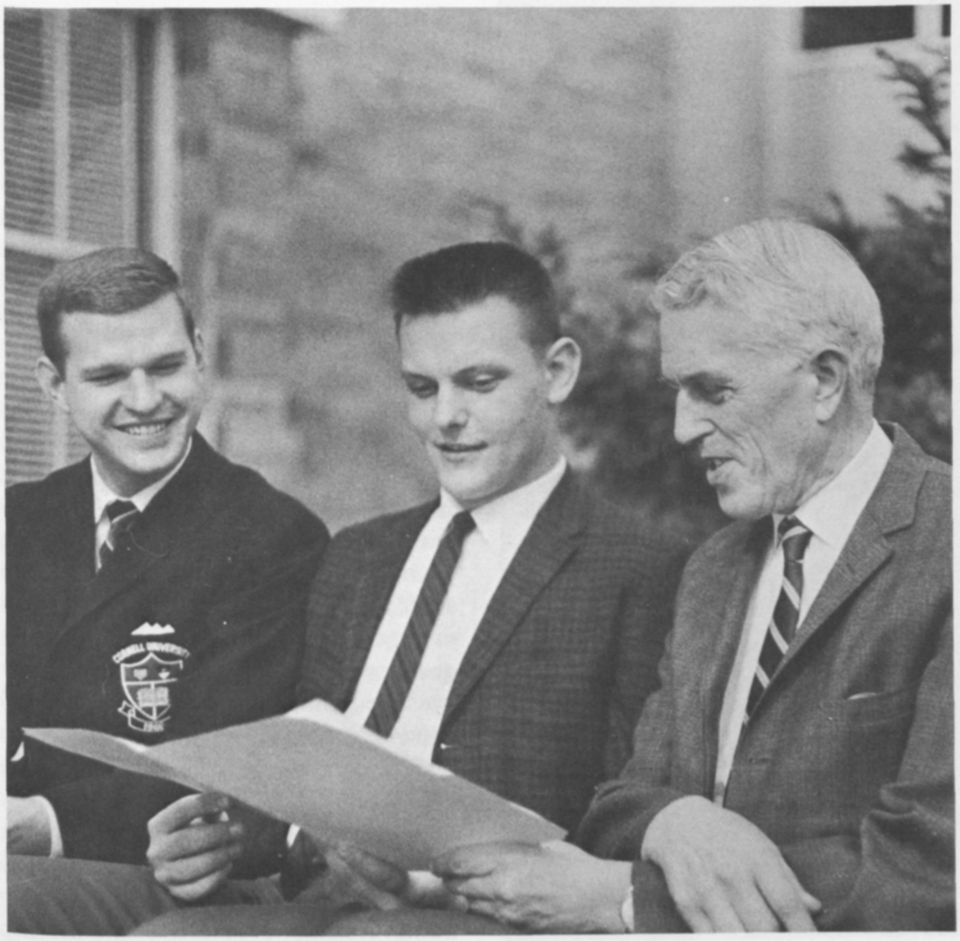
Cornell emphasizes design, for example, in the professional Master of Engineering program of the Sibley School of Mechanical Engineering. Problems for which there are no known solutions are posed to graduate students as part of their training. Such work is assigned on the premise that engineering problems can't always be dealt with through textbook knowledge alone. While many aspects of technical problems may lend themselves to "right" answers, the integration and weighing of various parts of a total problem are too often passed over in the classroom in the interest of "right" answer expediency.

SIMULATING A PROFESSIONAL ENVIRONMENT

It is relatively easy for an educational institution to provide an environment conducive to research. However, to simulate a professional engineering practice with all the attendant realities of time, money, and division of labor is more difficult. To do this, there must be individual and team efforts, problems both narrow and interdisciplinary in scope, and consideration of components as well as systems. When schedules are not imposed, the research and development climate of industry can be approximated. A production atmosphere is simulated when students work simultaneously on several problems within a schedule.

Because most students approach engineering design projects knowing basic engineering and scientific principles but knowing little of the specific technologies involved, their project advisers encourage them to seek out the faculty members who are most familiar with the various technical areas. This gives the students a greater sense of the many technologies and engineering fields that may be drawn into the solution of a single problem. Further, as in industry, they learn to educate themselves in areas where they lack proficiency and learn to seek the help of experts.

"This professional participation helped make the problems parallel real-life design engineering and kept them from lapsing into academic exercises."



An outline of the work done by the students in one course illustrates the practical and professional nature of engineering design education. Thirteen candidates for the Master of Engineering (Mechanical) degree were enrolled in the "Mechanical Engineering Design Project" course. The first problem was common to all of them: to design a thermoelectric generator for experimental development by a company interested in eventually marketing such a product. After preliminary design development by the class, each student worked on his own version of the hardware needed.

Each Master of Engineering (Mechanical) candidate presented his contribution to his team's design problem solution. In most instances, visiting engineers from industry were present to assess a team's work. Here, Professor Alexander Luce discusses the presentation to be made by members Frank Spencer and Michael Hanchuck of the student "consulting firm," Memech 67 Associates.

DESIGN REALISM FOR THE CLASSROOM

By Alexander W. Luce

Figure 1

PROBLEM	COMPANY
Improved chart drive	Taylor Instruments Co.
Design of a calibrated relay	Taylor Instruments Co.
Industrial air-jet vacuum cleaner	
Mobile facility for reduction of junk autos to marketable scrap	
Hydrofoil model testing tank	Grumman Aircraft Engineering Corporation
Controlled atmosphere supply for auto engines on dynamometer test	
Lunar rover traction design	Cornell's School of Mechanical Engineering
One cubic foot pressure vessel for 20,000-foot ocean submergence	Westinghouse Oceanographic Research Laboratory
Decollator for attachment to computer print-out equipment	Cornell Office of Computer Services
Mechanized orientation of glass fibers for fiber optics applications	Welch-Allyn, Incorporated
Disposition of unavailable energy from the Mine-mouth Steam Electric Station at Homer City, Pennsylvania	New York State Electric and Gas Corporation, Gilbert Associates, Consultants

The students then worked in teams on a variety of research and development projects that were solicited from industry. One of them was to provide a climate for a manned earth satellite. Engineers from Grumman Aircraft Engineering Corporation provided the statement of the problem, consulted with the students, and gave project critiques when the students presented the results of their work to their classmates and to the faculty. Carrier Corporation's Research and Development Division, in a similar manner, requested the design of a complete test facility for establishing the ratings of a wide range of fans. Further, the Carrier engineers assisted two independent student groups working on widely divergent answers to the same basic question: "What improvements are possible in mechanical refrigeration of goods in transit?"

The thirteen students then formed a "consulting firm" which they called Memech 67 Associates. Meeting as a committee of the whole they and their instructors proposed nearly ninety design areas for consideration. Of these, *"This professional participation helped make the problems parallel real-life design engineering and kept them from lapsing into academic exercises."*

they selected twelve on the basis of factors that an engineering consulting firm would take into account. Various industries were contacted for actual problems that would match the areas in which the students had indicated an interest. For eight of the proposed areas, industrial contacts were obtained. Most of the industries also helped the students by correspondence or telephone, and by critique at the end of their projects. These industrial problems for Memech 67 Associates were formulated in a variety of ways: as inquiries from investment houses, exchange of correspondence, intracompany memoranda. The "firm" was thus confronted by customer needs and restrictions typical of a professional situation.

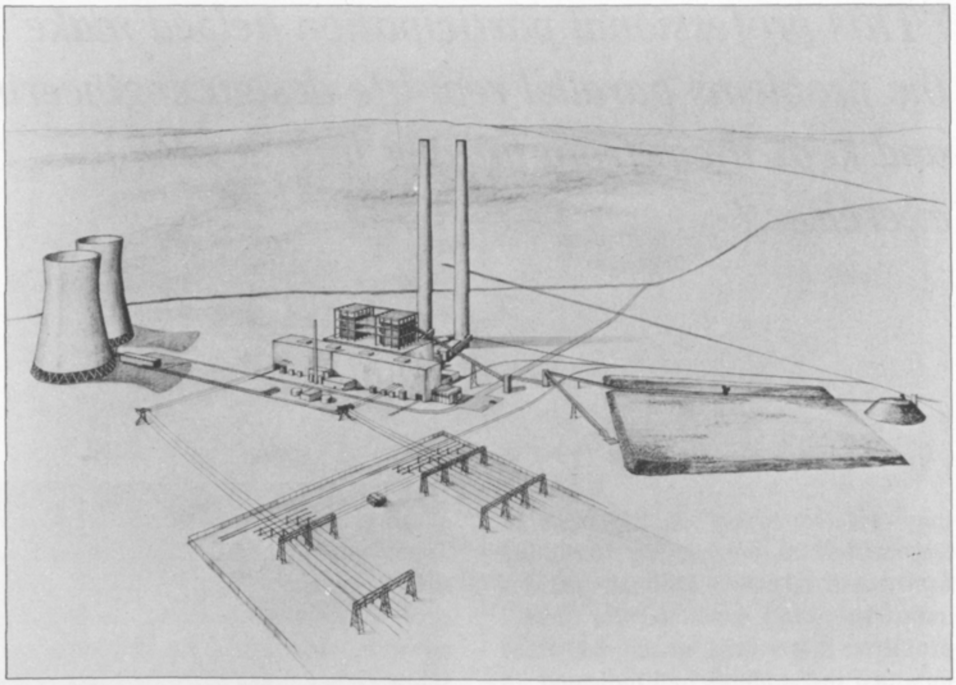
When contacted, Taylor Instrument Company, for example, offered an actual memorandum from its sales department to its engineering department which called for a specific instrument improvement and gave the estimated allowable costs and sales potential. A Cornell faculty member requested that preliminary work be done on an earth simulator of a lunar rover. The Westinghouse Oceanographic Research Laboratory requested that, given certain specifications, the firm design a one cubic foot pressure vessel for ocean submergence down to 20,000 feet. This professional participation helped make the problems parallel real-life design engineering and kept them from lapsing into academic exercises.

STUDENTS DESIGN A POWER PLANT

One team of students chose the last problem listed in Figure 1, the mine-mouth steam electric station at Homer City, Pennsylvania. This station, when it begins operation in 1969, will have one 640 megawatt unit and a 215-mile high tension transmission line extending to the New York State Electric & Gas (NYSE&G) Corporation facilities at Binghamton, New York. A second unit will be built in a year and provision is being made for a third. In mid-May when the team presented its design plans, three engineering experts participated in the program: Mr. A. D. Tuttle, Vice President for Engineering Planning for NYSE&G; Mr. E. K. Hess, Mechanical Engineer and Project Engineer for the Homer City plant, with Gilbert Associates, project consultants; and Mr. James J. Harlow, Vice President and Executive Engineer for the Philadelphia Electric Company, and President of the American Society of Mechanical Engineers.

Mr. Hess's review of the students' work made clear the number and complexity of factors involved in the mine-mouth problem. His review was a further learning experience for them as he called to their attention factors which, because of lack of time, experience, and knowledge, they had overlooked:

> Your assignment was limited to the solution of the problem of how to reject the waste heat from two 600 megawatt turbine-generator units at the rate of approximately 2.7 billion Btu/hr per generating unit. . . . Your approach was good. It was immediately recognized that cooling towers would be required. Your study to select the type of cooling tower was complete and accurate. The



Above: An artist's rendering of the Homer City, Pennsylvania, power plant showing the mine-mouth on the right, the means of transporting coal to the plant for processing; and, on the left, the two hyperbolic natural draft towers which were central to Memech 67 Associates' design problem.

An aerial view of the Homer City site. In the distant background note the foundations for the two hyperbolic natural draft towers.

dry type tower was first eliminated in favor of the wet type due to the resulting high back pressures and the state of the art. This same conclusion was reached in the [actual] design of the Homer City station. After rejecting the dry tower, you compared the two types of wet towers, the force draft and the natural draft. Your economic comparison properly considered first cost, operating cost, and reduction in net plant capacity. Your conclusion in favor of the natural draft tower further considered availability, ground fogging, and space requirements. As you know, the same conclusion in favor of natural draft towers was reached in the design of Homer City. . . .

After determining the basic design of the cooling system, that is natural draft cooling towers and surface condensers, the study properly progressed to consider:

1. turbine selection
2. condenser-cooling tower size optimization
3. provision for a suitable makeup water supply

The approach to the first item is a straightforward economic evaluation which considers the first cost of various size turbine-generator units versus operating costs of those units at the back pressures expected in a cooling tower installation. The conclusion selecting the smallest turbine adequate to meet the capacity requirements is in the right direction as dictated by the low fuel costs anticipated. . . .

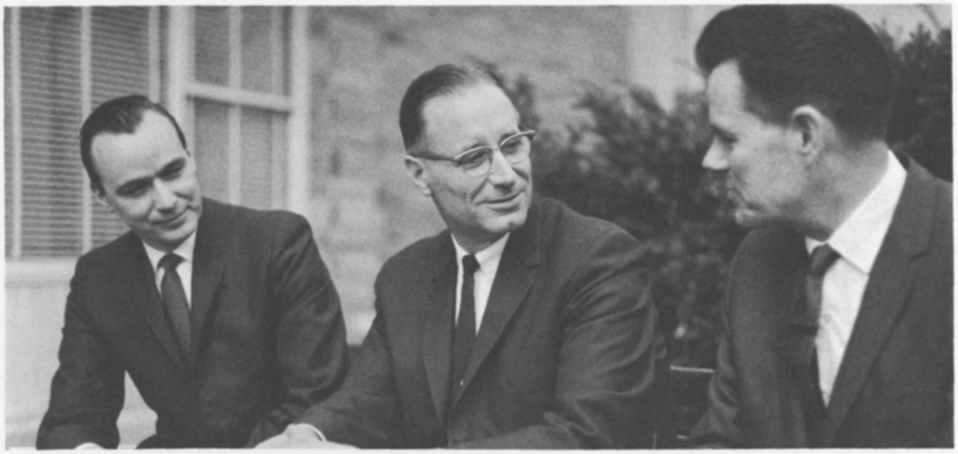
For the second item, condenser-cooling tower optimization, the [student] report presents in considerable detail data to be incorporated in a further study. It correctly recognizes that this is a rather massive data-processing problem readily adaptable to a computer solution. It further recognizes that the multi-stage condenser offers increased returns when considered in the final design. . . .

The third item, makeup water supply, required several phases. First, it was recognized that the flow in Two Lick Creek was not adequate to make up for the evaporation and blowdown from the towers during much of the year. Both wells and pumping from a remote body of water were rejected as being expensive and unreliable. It was then concluded that a storage reservoir would be needed to store water in the wet season to be available during the dry. Water flow records were utilized to determine the deficiency in flow and hence the required reservoir size. Topographical maps were studied to determine the availability of suitable dam sites and a dam was selected. As a matter of interest, the site proposed is just one mile downstream from the site actually selected for the project.

So that I don't make you gentlemen overconfident of your ability in this work, I should point out that there is a much superior site available nearby on Yellow Creek. It is suitable for a less expensive earth fill dam and side channel spillway. This, unfortunately, was not available for the project because someone else thought it was a good dam site too. The state is building a dam and reservoir there for recreational purposes.

The chemical properties of the stream are such that cooling-tower blowdown will be greatly increased over what you had assumed. Also the state has established requirements to maintain minimum flow in streams below dams and plants which consume water. . . . Another very significant fact affecting reservoir size was that the owners require that the plant be designed to be expandable to add at least a third 600 megawatt unit. So the design lake is considerably larger than you propose and extends about five miles along the stream from dam to backwater. . . .

Memech 67 Associates is to be congratulated. Every one of your conclusions was utilized in the final design of the Homer City station. In a very short time you



Mr. E. K. Hess, left, of Gilbert Associates; Mr. A. D. Tuttle, center, of the New York State Electric and Gas Corporation; and Mr. G. E. Lien of the American Electric Power Service Corporation gather to discuss the students' mine-mouth problem presentations. Mr. Lien addressed the students on the challenges in power plant design. Several other practicing engineers participated in the final design evaluation sessions. Through their critiques, the students were able to compare their work with that in current professional design practice.

have approximated what took considerable effort to establish in the design of a real $150 million power plant. You have produced a fine piece of engineering.

The benefit of the professional training provided by this problem and by the others from Grumman, Carrier, Westinghouse, Welch-Allyn, and Taylor Instrument is obvious. Equally important is the association of visitors from industry with the faculty, an association that may greatly strengthen professional engineering programs in the future.

Alexander W. Luce, Emeritus Professor of Engineering at Norwich University, was Visiting Professor of Machine Design in Cornell's Sibley School of Mechanical Engineering from 1965 to 1967. Born in Minneapolis, Minnesota, he earned the Bachelor of Science degree in 1921 and the degree of Mechanical Engineer in 1923, both from the University of Minnesota. Professor Luce has had an extensive career in teaching and in industry. From 1926 to 1928 and again from 1930 to 1940 he was a member of the faculty of Lehigh University. In 1940 he assumed the duties of professor and head of the mechanical engineering department at the University of Connecticut. He joined The Fellows Gear Shaper Company of Springfield, Vermont, in 1942 and returned to teaching in 1946 at the Pratt Institute. At Lafayette College, where he joined the faculty in 1953, he headed the mechanical engineering department until he moved in 1957 to Norwich University. The honorary degree, Doctor of Engineering, was conferred on him there in 1964.

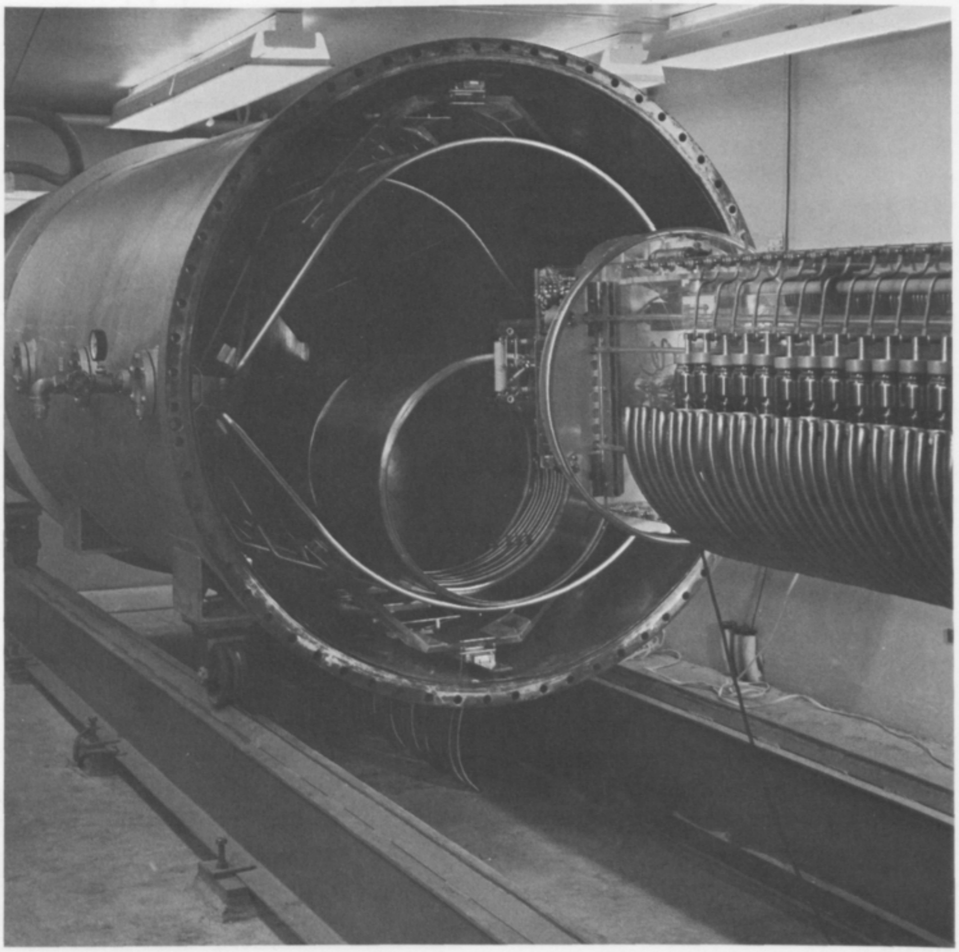
Professor Luce has authored three books: Machine Design, Engineering Standards, *and* Steam and Gas Engineering *(with Butterfield and Jennings). He has written engineering articles for the* Encyclopedia Americana *and the* Encyclopaedia Britannica. *He is a member of Theta Xi, Pi Tau Sigma, Tau Beta Pi, the American Society of Mechanical Engineers, the American Gear Manufacturers Association, and the American Society for Engineering Education. He has served on and chaired important committees for the latter three organizations. Professor Luce is a registered professional engineer in New York, Pennsylvania, and Vermont.*

Now retired to his home, Sunny Mowings, in Springfield, Vermont, he maintains a consulting practice with the Riley Stoker Company in Worcester, Massachusetts, and with various legal clients.

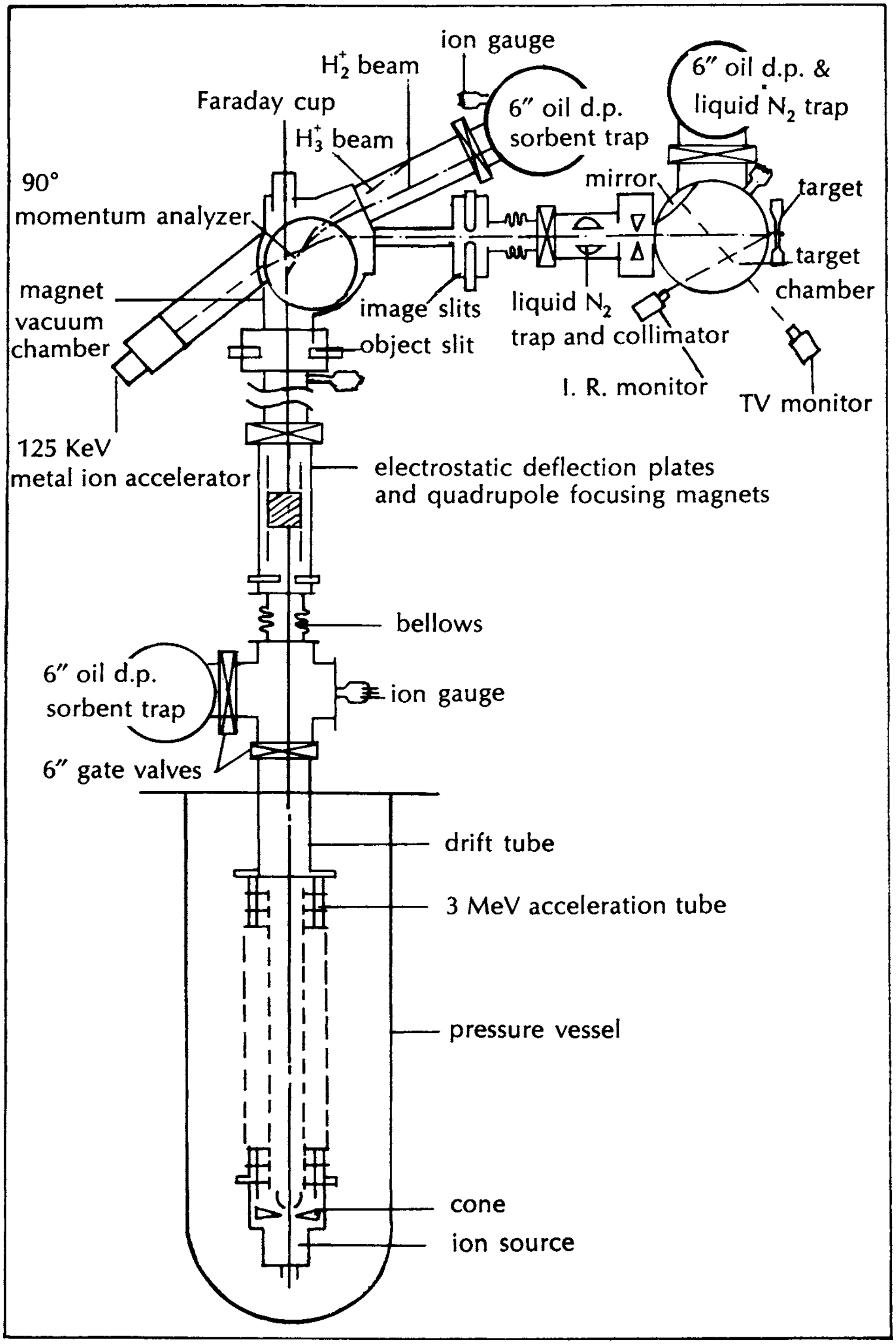
VANTAGE

The use of high voltage accelerators which propel atomic and subatomic particles to almost the speed of light in order to study the structure of matter has taken two different courses. In high energy physics, such powerful machines as the 33 BeV Brookhaven accelerator and the projected 200 BeV accelerator at Weston, Illinois, are used to break down resistant cores of matter. Less well known is the application of lower voltage accelerators to the study of materials structure and to materials processing research. An interest in this field has developed only in the past five years.

Cornell's accelerator, the Dynamitron, is a lower voltage instrument. Located in the basement of the Nuclear Reactor Laboratory, the Dynamitron is used in conjunction with a TRIGA 100 kw reactor and with a 10,000 curies Co^{60} gamma cell to study problems in nuclear science and in materials. The Cornell machine is a high current d-c instrument with a maximum terminal

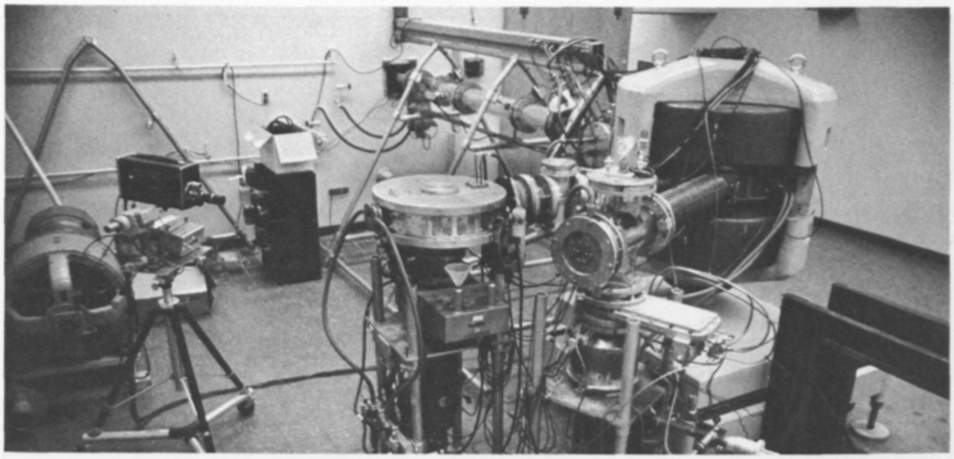


The Dynamitron's pressure vessel showing the acceleration stack.



The diagram shows how the protons are propelled through the Dynamitron. The positively charged particles are initially separated from the negatively charged ones in the source and are extracted by the cone which is located just outside the source. The positively charged particles are introduced into the acceleration tube where their velocity is raised to the same overall level. At present, using a potential drop of 2.5 MeV across the acceleration tube, 4 milliamperes of beam current can be obtained, that is, 10 kw of the potential power. Electrostatic deflection plates and quadrupole focusing magnets at the base of the machine direct the protons through the entry slits of the analyzing magnet which deflects the particles into the target chamber. Those that are not of the desired velocity are deflected into the H_2^+, H_3^+ beam catcher. The proposed joining of the 3 KeV accelerator to the Dynamitron is shown.

1



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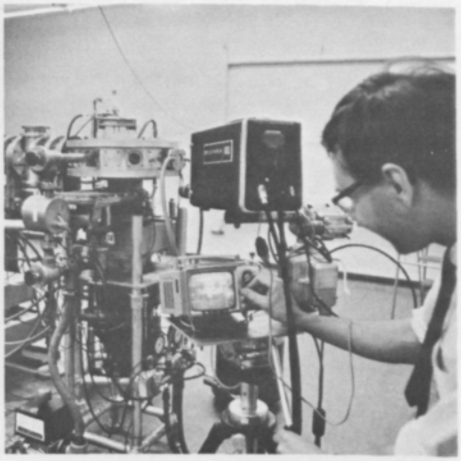
1. *Target chamber containing the Dynamitron's drift tube which directs the particles to the magnet, right, which bends their course toward the target, foreground.*
2. *Professor Anthony Taylor, left, and students check the target chamber by remote TV monitor at the control console.*
3. *Aligning TV camera on neutron target.*

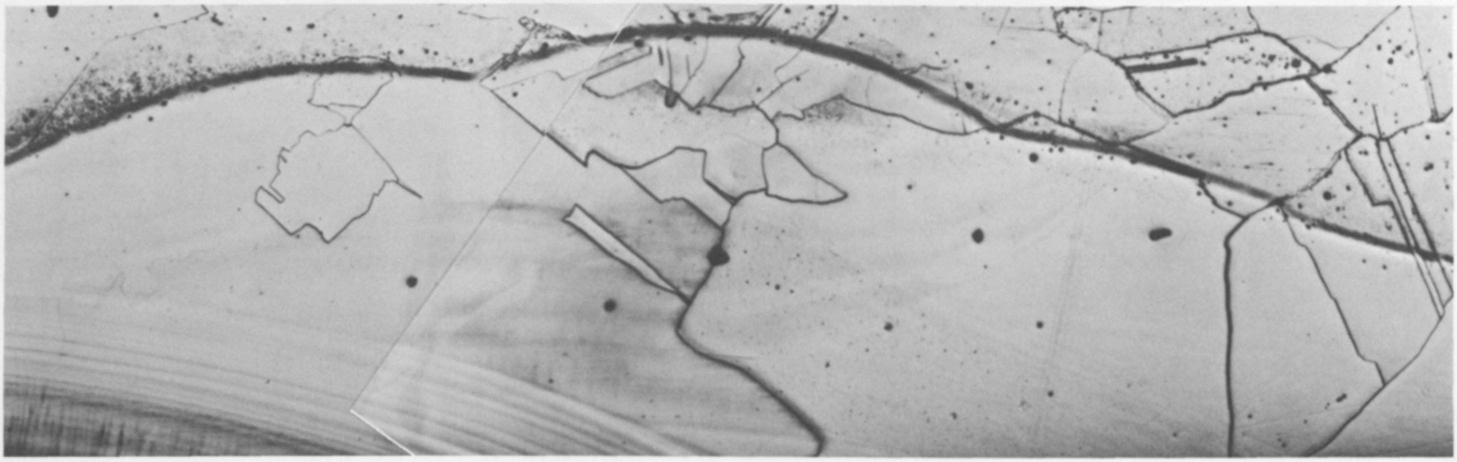
3



ENERGY OF INCIDENT PARTICLE	TYPICAL DEPTH OF PENETRATION	NAME OF PROCESS
0.1 eV	surface deposit	evaporation
10 eV	surface deposit	sputtering
1 KeV	1 atom	ion-plating
100 KeV	25 atomic spacings	ion-implantation

potential of 3 MeV. The high current power supply, based on a novel modification of the Cockroft-Walton principle, gives the machine maximum capacity to deliver a 30 kw beam. The unique feature of the Dynamitron is that, with suitable targets and transport equipment to handle intense beams, high fluxes of monoenergetic neutrons can be obtained. These features provide greater control of the neutron flux than can be obtained by using, for example, a TRIGA Reactor, and they greatly simplify and add to the exactitude of experimental work.

Unlike the very highly accelerated particles produced by a 33 BeV machine, which randomly smash apart particle configurations in their paths, the less energetically propelled Dynamitron particles "nudge" the atomic particles of the target material out of place, sometimes lodging within its structure. These lightly charged ions tend to flow through the spaces within the atoms of a crystalline target material unless they meet an obstruction such as a lattice defect or meet one of the bombarding ions that has lodged in a space channel. A "picture" of the



target's atomic structure becomes apparent as the backward spray of the bombarding particles that have met obstructions is observed and as the flow of particles through the spaces within the atoms is noted. Further, by turning or tilting the target at various angles, thus placing more or fewer atoms in the path of the bombarding particles, a picture in depth of the lattice defects in the host material can be inferred. Researchers can then answer such questions as: What is the distribution of bombardment damage? Where and what are the natural defects in the host material? How much energy is required to move particle *x* from position *A* to position *B*? Given a certain angle of reception and a specific amount of energy for particle bombardment, particle *x* moves in *y* direction; if the energy of bombardment is varied, will particle *x* move at all, or will it move in a slightly different direction? Knowing the energy required to move particle *x*, can we determine the "distance" from *A* to *B?* If bombarding particles lodge within the structure of the host material, how is the material changed?

The answer to the last question is particularly significant in relation to ion-implantation processes, one of the practical uses of the lower energy accelerators. The surface of a material can be alloyed simply by driving solute atoms into the surface at a velocity high enough to produce the required depth of penetration. Thus, the surface layers of any solid material can be adjusted by alloying it with any solute from the Periodic Table. Commercially this technique has great potential because it permits the design of materials for specific uses. For example, Dynamitrons are being used to fabricate, but more to shape, semiconductor and solar cells. Because even lower energies are more suitable for actual fabrication of semiconductor junction structures, an additional accelerator of 3 KeV will be joined to the Cornell Dynamitron. The junction of the two accelerators will greatly extend the range of energies that can be investigated. The 3 KeV accelerator's low energy back scattering should provide important diagnostic information about the nature of the damage already done by higher energy Dynamitron particles.

Ion-implantation experiments on semiconductor junction structures are being initiated by Professor Charles Lee with the support of a Rome Air Force Development Center contract. Other work to be initiated at the Dynamitron facility includes Professor Ross McPherson's study of the nuclear structure of light elements by accelerating the isotope He^3, and Professor David Seidman's study of radiation damage in metals using a field-ion microscope. Under terms of a contract with the Atomic Energy Commission, the Cornell Dynamitron is presently being used to study radiation damage in crystalline solids. The study of radiation damage by neutrons as a function of neutron energy is a new, rapidly expanding field which is very important in many research areas, including missile studies.

Opposite: Changes in structure of copper target induced by intense bombardment.

REGISTER

■ In keeping with the organizational changes being made throughout the College of Engineering, a School of Engineering Physics and a Department of Applied Physics have been created to replace the Department of Engineering Physics.

Since its founding in 1946, the Department of Engineering Physics has earned distinction for its contributions to modern engineering education. Its teaching program, in which the fundamental and applied sciences were combined, has been a model for many other engineering colleges. The more than 400 alumni of this Department have shown extraordinary ability in the traditional fields of engineering and in the developing technologies.

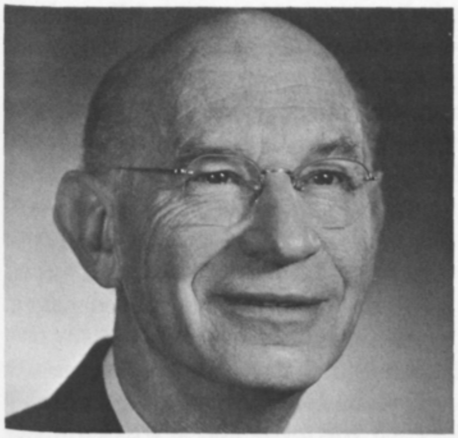
In 1946, when nearly all other colleges of engineering educated students for professional practice and defined their curricula according to the needs of the practice, Cornell's Engineering Physics Department began training the engineer of tomorrow by showing students the evolution of physics principles and how they might be applied to engineering problems of the future.

To further this kind of instruction throughout the College, the overall plan is to establish Schools for teaching undergraduates and for administering the Bachelor and Master of Engineering degree programs, and Departments for administering graduate programs leading to the Master of Science and doctoral degrees. Through the Departments, the College of Engineering will be able to maintain leadership at the basic-applied science interface and will be able to ensure the timeliness of the undergraduate curricula. The new Department of Applied Physics will develop those areas of physics which show promise for future engineering application.

The chairman of this Department is Norman Rostoker who has also been named IBM Professor of Engineering, a chair endowed by the International Business Machines Corporation and the Ford Foundation. Before coming to Cornell, Professor Rostoker was the manager of fusion and plasma physics at General Atomic Division of General Dynamics Corporation where his principal interests were plasma stability, finite Larmor radius effects in plasmas, and variational principles and fluctuations in plasmas. Since 1962, he has also served as professor of physics at the University of California at San Diego.

A native of Toronto, Professor Rostoker holds both the Bachelor's and Master's degrees from the University of Toronto and the Doctor of Science in Physics degree from Carnegie Institute of Technology. Before joining General Atomic, he was head of the theoretical physics group at the Armour Research Foundation.

The director of the new School of Engineering Physics is Trevor R. Cuykendall, Spencer T. Olin Professor of Engineering. Professor Cuykendall was instrumental in founding the engineering physics program in 1946, developed the University's first course in nuclear engineering in 1952, and helped to develop the graduate program for the Field of Engineering Physics. He has been a member of the faculty of the College of Engineering for more than twenty-five years. In addition to his Cornell responsibilities, he is a consultant to the Nuclear Engineering Division of the Atomic Energy Commission.



Cuykendall

Rostoker

■ FREDERICK S. ERDMAN

After earning two undergraduate degrees (Bachelor of Science in Arts and Sciences, Princeton, 1924; Bachelor of Science in Mechanical Engineering, M.I.T., 1927) Professor Frederick S. Erdman came to Cornell in 1937 expecting to stay just one year for a Master of Mechanical Engineering degree. He found himself returning for a Ph.D. in 1941 and then remaining for the balance of his active professional career. Before coming to Cornell permanently, Professor Erdman had considerable teaching experience, first as a physics instructor at Beirut University in Lebanon where he was born and later as an assistant professor of mechanical engineering at Robert College in Istanbul.

During the 1940's when the science of food freezing was in its infancy, Professor Erdman began research into the construction of home food freezing equipment. This work furthered the development of a now large industry. During the latter part of World War II, he designed a freezer that could be built by a home handyman.

After long teaching experience, Professor Erdman is keenly aware of the professor's need for contact with the nonacademic world of engineering. His two sabbatics, the first in 1948 at Brookhaven, examining the role of atomic energy in power generation, and the second in 1955 at the Cleveland Electric Illuminating Company, helped him to bridge this gap.

Since 1961 Professor Erdman has been associate dean of the University's Graduate School in charge of the graduate fellowship program.

Professor Erdman has been active in the American Society of Mechanical Engineers, the American Society for Engineering Education, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, and the American Association of University Professors of which he was Cornell Chapter President from 1954 to 1956. During 1961 he was secretary of the University faculty and ex officio member and secretary of the University Faculty Council. His honoraries include Phi Kappa Phi, Sigma Xi, Tau Beta Pi, and Pi Tau Sigma.

Erdman

Gregg

■ JAMES L. GREGG

Before coming to Cornell in 1948, Professor Gregg had extensive experience in industry and through consulting work has continued this part of his career.

After graduation from the Missouri School of Mines in 1923, he went to the Illinois Steel Company in Gary, Indiana, as a metallurgical observer. A year later he became metallurgical engineer and department supervisor at the Western Electric Company in Chicago. In addition to these duties, he taught from 1927 to 1929 at the Lewis Institute, which merged with the Armour Institute in 1940 to become the Illinois Institute of Technology. From 1929 to 1934, he was affiliated with the Battelle Memorial Institute in Columbus, Ohio, as research metallurgist. For the next ten years he was a research engineer for the Bethlehem Steel Company and then served the firm as assistant to the vice president from 1944 to 1948. During summers, Professor Gregg has regularly been a consultant to the Oak Ridge National Laboratory, and he spent a year there in 1954–55 while on sabbatic from Cornell.

Professor Gregg has been a member of the Research and Development Board Committee on Basic Physical Sciences since 1948 and a member of the Die Casting Foundation from 1952 to 1955. At Cornell, he has been a member of the Materials Science Center in charge of materials preparation.

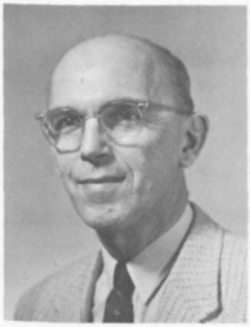
Professor Gregg's wide-ranging industrial experience has been an asset to his teaching. He hopes that the tremendous expansion of engineering facilities at Cornell, which has expedited his own work and benefited his students, will continue.

■ GEORGE R. HANSELMAN

Professor Hanselman has combined a no-nonsense attitude with one of sympathy in his dealings with students as assistant director of Cornell's Sibley School of Mechanical Engineering for the past twenty years. Helping engineering students to cope with their problems has been Professor Hanselman's greatest satisfaction. He feels too much is heard about the student minority that is irresponsible and too little about those who are conscientious. In recent years, Professor Hanselman has found that many of his students aren't as sure of their goals as their predecessors were. This is perhaps a function of today's more intensive social climate, but is a function, too, of the greater uncertainties and pressures in their futures.

In addition to student counseling, Professor Hanselman finds satisfaction in his visits with the alumni who return to see him. Having been associated with Cornell for forty-nine years, Professor Hanselman has attended forty-five reunions and enjoys keeping up with class affairs. He took two Cornell degrees: Bachelor of Science in Mechanical Engineering in 1922 and Master of Science in Mechanical Engineering in 1936.

Not only has Professor Hanselman been active in curricula planning, student personnel, and in the general administration of the Sibley School of Mechanical Engineering, but he has also been active in other Cornell engineering activities as, for example, chairman of the College Faculty Committee on New York State Community Colleges and



Hanselman

Richards

Baird

Strong

Technical Institutes, chairman of the College of Engineering Scheduling Committee, and on the Joint Faculty Committee on Agricultural Engineering. He is a member of the American Society for Engineering Education and the National Association of Cost Accountants.

■ WILLIAM L. RICHARDS

Coming to Cornell after thirty years of government engineering service, Professor Richards wryly says that he had expected to find teaching a relaxing occupation with plenty of time for reflection and reading. His purpose in coming to Cornell was to teach and to be with young people; this has fully filled his schedule. He has found it particularly rewarding to have been able to relate his long professional experience to the classroom.

Reflecting on education, Professor Richards feels that, nationally, college science and engineering programs are not developing talent across a broad front. The emphasis on research and the de-emphasis on engineering applications has tended to narrow the field for prospective students; thus the talents of many capable young people are being lost.

Professor Richards' refreshingly optimistic view of students is that they are unspoiled and highly motivated and are often given inadequate guidance. He feels that a better job of recognizing their problems and frustrations could be done. For his own students, Professor Richards has maintained consistently high standards and has always hoped that each student would merit high grades. He has been generous with his time in student counseling as well.

Professor Richards holds his Bachelor of Science degree from the United States Naval Academy (1924) and the degrees of Civil Engineer and Master of Civil Engineering from Rensselaer Polytechnic Institute (1927 and 1928). He is a member of the American Society of Civil Engineers, a fellow of the Commission on Education of Construction Engineers, and a member of the National Society of Professional Engineers, American Society for Engineering Education, and Sigma Xi.

■ THOMAS J. BAIRD

Thomas J. Baird, Professor of Machine Design and Materials Processing, brought an energetic, vital architect's outlook to the traditional drafting approach to engineering problems. There are likely to be multiple solutions to any problem, and he has taught his students to work through the implications of each solution. Further, he has stressed what a design means in terms of society, utility, and esthetics. His sketching course has helped many students to "loosen up" and express themselves more creatively on engineering problems.

Most of all, Professor Baird enjoyed his small, intimate senior classes in industrial design where the talk of engineering problems was sometimes far-flung, reaching into the social areas related to engineering. He recalls that many of his students displayed an innate feeling for form and proportion as well as a surprising awareness of social problems.

Two years ago, Professor Baird was a co-recipient of the Philip Sporn Prize, endowed by the noted power industrialist Philip Sporn to recognize excellence in freshman teaching. Professor Baird is a member of Tau Beta Pi, the Industrial Designers' Society of America, and the American Association of University Professors. He holds two Cornell degrees: Bachelor of Architecture, 1925; and Master of Regional Planning, 1946.

Apart from teaching, Professor Baird is proud of the Twin Groves settlement that he and several other faculty members have developed on Cayuga Heights Road in Ithaca. He designed several houses for this project as well as other houses in Ithaca.

Professor Baird looks forward to the freedom of retirement for travel, painting, and perhaps more architectural work.

■ EVERETT M. STRONG

For Everett M. Strong, Professor of Electrical Engineering, the freedom, blending of science and the humanities, and varied campus life of Cornell have made it a stimulating place for him to teach and an ideal place for students to develop.

After obtaining his Bachelor of Science in electrical engineering from M.I.T. in 1922, he went to work with the General Electric Company in Cleveland. During his last two years there, he taught a night course that had to appeal both to teenagers who wanted to learn the basics of electricity and to adults who wanted more sophisticated information. He had such success in reaching these people that he decided on a career in teaching.

Professor Strong's industrial experience aided him in teaching. But a professor can transfer only a limited amount of his practical experience to the classroom—the student needs practical experience of his own. Professor Strong's understanding of this fact and his ability to articulate the problems that confront a student entering industry have spurred the Industrial Cooperative Program which he has directed for more than twenty years. As Professor Strong says, all engineering isn't to be learned in books. Thus, the Cooperative Program, which strengthens professional development through actual work in industry, is very important. He stresses that on campus it isn't possible to expose students to the situations, equipment, and, especially, the environment that they encounter in industry. Whereas competition is often foremost in university life, cooperation is more the keynote in industry. Further, he notes that after a short time in industry, students often bring broadened perspectives to their college work. This program, he is quick to point out, hasn't all the answers, but it often saves "heartache."

Last year Professor Strong received the Illuminating Engineering Society's Gold Medal in recognition of his leadership in research in programs in light and vision. His honoraries and listings include Tau Beta Pi, Sigma Xi, Eta Kappa Nu, *American Men of Science, Who's Who in the East, Who's Who in America,* and *World Biography.*

FACULTY PUBLICATIONS

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