Research for Education

Advancement of M.I.T.'s Educational Objective Is Primary Factor Governing Acceptance and Priority of Sponsored Research

By James R. Killian, Jr.

RECALLED by all is the "long hairs vs. hairy ears" argument that followed World War II, and the repeated assertion that men trained in science, especially in physics, proved to be more effective at applied research than did the engineers. No doubt this assertion, if analyzed, can be shown to be a half-truth. Nevertheless, the half-truth that remains should force and is forcing a re-examination of some of our methods and procedures in engineering education, and of our use of research as a method of teaching.

The scientists ascribe their success in handling applied research during the war to several factors: The first is that they had advanced training and most of them held doctor's degrees. The second is that they had a fundamental training in science that was both broad and deep, with the result that they were able to bring to bear upon practical problems a wide range of scientific learning and a flexible method of thinking. The third is that the training which they had received and the environment in which they had worked promoted creative thinking of a quite untrammeled kind. They were not normally concerned by any practical or economic limitations and they were instinctively inclined to dream and speculate, with a bold indifference to limitations. Such unusually favorable conditions for research have seldom occurred before.

Now this kind of training and this point of view are not a monopoly of the scientist, and there are fields of engineering which have embraced them for many years. The fact remains that engineering, while retaining its capacity to work under practical limitations, must at the same time adopt more of the analytical tools of pure science and its willingness to question standard practice. The feeling is widespread in many institutions that research must be used throughout our engineering training to attract men of imaginative minds and to train engineers who have the temerity and capacity to dream and speculate beyond the boundaries of the immediately practical.

The engineering departments at M.I.T. have long been wedded to the principle that research and the research atmosphere are essential to the training of both undergraduates and postgraduates and that a balanced staff must involve creative competence as well as teaching competence. No doubt this tendency to deepen engineering education through stressing fundamental research is one of the most important changes now in process. While engineers must always maintain their firm hold on the economic and applied aspects of their art, they can enormously benefit by promoting within their ranks an increasing number of scholars with the courage to ignore conventional conceptions and with a comprehensive understanding of physical laws and analytical methods.

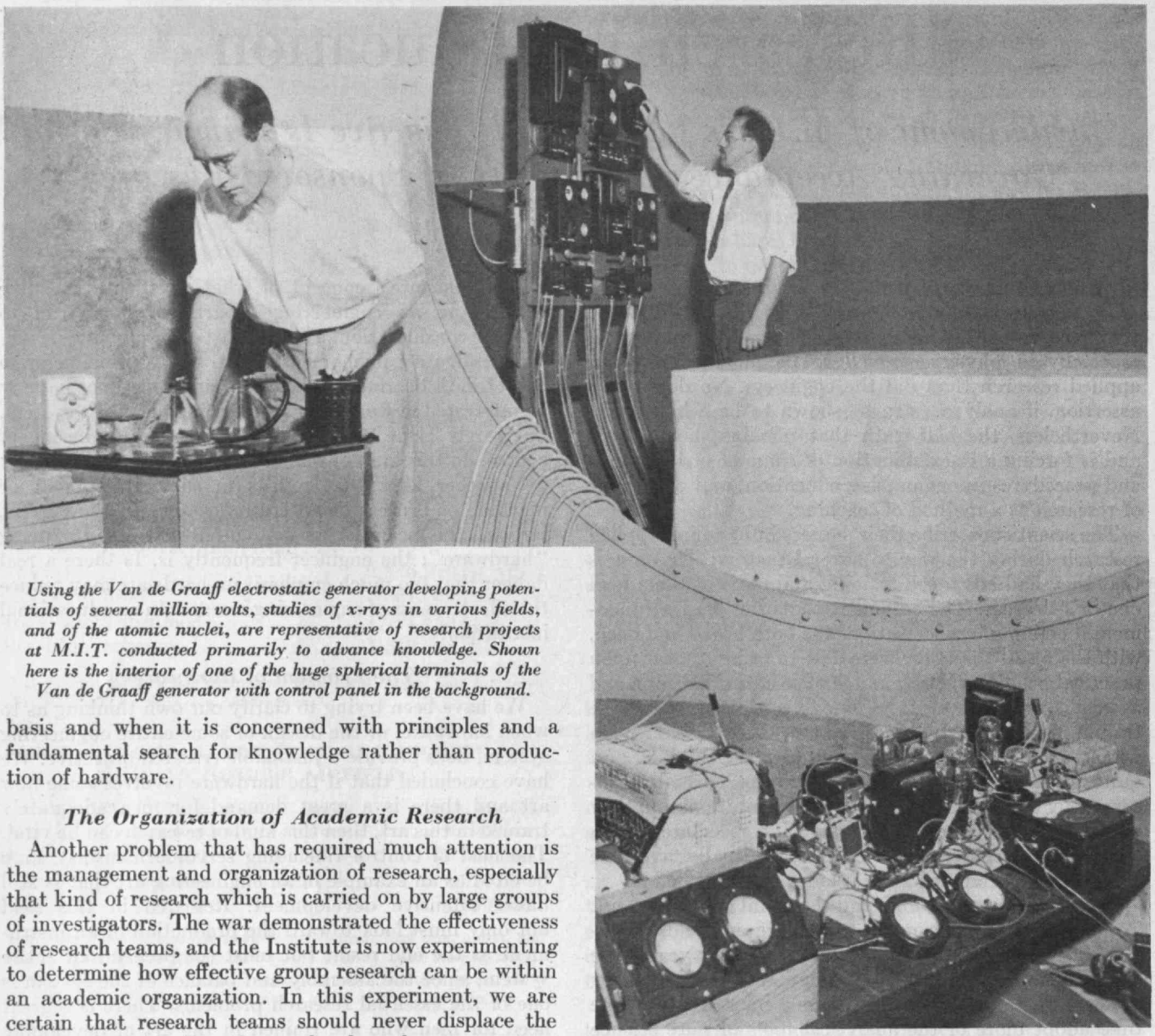
The Institute's concept of what constitutes effective research in an engineering department is subject to another consideration. The scientist generally undertakes to investigate a phenomenon or to seek a principle or to collect data bearing on a hypothesis. Sometimes he may be interested in working on some component of a system, but rarely is he interested in a system. Engineers, of course, do this kind of research, too, but frequently they do another kind that results in some instrument or machine or process or an entire system. In the current jargon, the scientist is not interested in producing "hardware"; the engineer frequently is. Is there a real danger that too much emphasis on hardware may reduce the effectiveness of engineering research in an educational institution?

The Problem of Hardware

We have been trying to clarify our own thinking as to when hardware, or the design of some entire engineering system, does provide a justifiable research objective. We have concluded that if the hardware involves some new art and there is a great demand for men adequately trained in this art, then this kind of research can be vital. The field of control (including servomechanisms), may be cited as an example of an engineering art that is still under intensive development. Research in this field not only must look toward the production of an instrument as the end result but must comprehend an entire system, since the assembly and balance of the system is one of the essential research problems. There is a great need for men who are trained in the art of developing dynamic control systems, and consequently any laboratory activity must deal with the over-all system.

This emphasis on system research in the control field justifies another type of research which might commonly be out of place in an engineering institution, that is research which involves the production of equipment. In control, and a few other fields, because of the importance of the systems aspect, the production of equipment involves a new art and a research technique which is essential in training men in the field at an advanced level. There is no way for these men to become effectively trained other than to work on a project which involves the production of control units. More importantly a systems project or the engineering of a piece of equipment can be an extraordinarily effective educational vehicle by requiring a synthesis of all that the student has learned.

At M.I.T. we believe that research or hardware or systems should meet these tests of educational validity. With these exceptions in mind, we believe that engineering research in an educational environment can be most effective when it is handled on a component, or unit,



Using the Van de Graaff electrostatic generator developing potentials of several million volts, studies of x-rays in various fields, and of the atomic nuclei, are representative of research projects at M.I.T. conducted primarily to advance knowledge. Shown here is the interior of one of the huge spherical terminals of the Van de Graaff generator with control panel in the background.

basis and when it is concerned with principles and a fundamental search for knowledge rather than production of hardware.

The Organization of Academic Research

Another problem that has required much attention is the management and organization of research, especially that kind of research which is carried on by large groups of investigators. The war demonstrated the effectiveness of research teams, and the Institute is now experimenting to determine how effective group research can be within an academic organization. In this experiment, we are certain that research teams should never displace the brilliant individualist who works alone, but we want to find out how the two approaches supplement each other.

One of the devices employed at M.I.T. to handle group research — and to stimulate individual work — is the "center of research" of which several are in operation. These are interdepartmental organizations which co-ordinate the co-operative activities of various departments in important fields of overlapping interest. While we call them centers of research because research is their predominant role, they are nevertheless playing a very important part in our educational program, especially by providing superior opportunities for senior and graduate student thesis work.

These centers of research appear to be a highly satisfactory answer to a problem which has long confronted educational institutions, namely, that of handling those interests which reach outside the traditional departmental boundary lines and require the co-operation of the specialists from several disciplines. Certain institutions have tried to meet this problem by setting up special institutes. Others have set up new departments. It is the feeling at M.I.T. that both of these solutions seem to be lacking in two desiderata: namely, the mobilizing of the interested personnel of the various departments into a co-operative whole while still recognizing each department's special interest in the various aspects of the program, and, most importantly, the full co-ordination of the research with the educational program.

Centers of research have been established in about half a dozen fields, but the first and the most highly developed of such programs is in the Research Laboratory of Electronics, which is operated jointly by the Department of Physics and the Department of Electrical Engineering. Some 65 graduate students are now doing their theses in this laboratory. It has a highly productive program of research that is managed by professors from the two collaborating departments and it maintains a concentration of equipment which is available to the staffs of the two departments.

We believe that this laboratory is serving as a pilot plant for a new type of internal collaboration among departments having the fundamental scientific point of view and departments having the applied point of view. Through such mechanisms as this we hope to effect a fruitful cross-fertilization and thus minimize the dif-

ferences which distinguish the engineer and the scientist. Joint laboratories of this kind also provide a means whereby the educational staff can cope with large-scale sponsored research. These laboratories provide a staff of administrative officers and services which free the educational staff from routine work, thus permitting them to concentrate on their educational and research activities.

Contract Research — Its Values and Limitations

Coming now to some of the special problems of sponsored, or contract, research, there are several guiding principles which have been laid down at M.I.T. and this article describes some inherent difficulties.

The first of these guiding principles is that the primary purposes of an educational institution are to educate men and women and to increase knowledge, not to compete with industry in industrial research or production for profit or to undertake activities which are the special responsibility of governmental agencies. Two factors may justify a secondary activity in the realms of these industrial or governmental interests: One is the importance of case material in any effective professional education. The other is the responsibility of an educational institution to render public service when it can do so without impairing its primary functions and when its personnel, facilities, or experience especially qualifies it to perform a needed service which cannot be performed adequately or in time by some other agency.

Our second guiding principle is that sponsored research should be closely related to the normal program and recognized objectives of the institution. It should involve only work which can be carried out with enthusiasm by the staff and it specifically should not be work which the staff would undertake with reluctance and which would be unrelated to their educational and professional programs. A member of the Institute's staff is never "assigned" to contract research.

The third guiding principle is that imposition of restrictions on publication of research results, either for secrecy or patent reasons, can become incompatible with the basic concept of an educational institution as a source and distributor of knowledge. Research contracts involving such restrictions, especially long-term or permanent restrictions, should be undertaken only for exceptional or emergency reasons. No arrangement is permitted which could inhibit free and effective work by the institution in any scholarly field. No project is normally accepted unless it is open to qualified students.

Our fourth guiding principle is that the compensation and privileges available to the academic staff, including graduate students who are members of the staff, must never suffer in comparison with the emoluments available to staff engaged solely for contract research. This policy is of the greatest importance, since funds available for contract research frequently are less restricted than funds available for the regular academic program, and there is a consequent temptation to pay higher salaries to the personnel working on these projects.

The Institute has carried out this policy of protecting the academic staff by distinguishing sharply between the academic staff, with its educational function, and the nonacademic staff employed specifically for contract research. The academic staff has important privileges, such as tenure, membership in the pension association, opportunity for graduate study, time for outside consulting, and extended vacations. None of these privileges is available to the nonacademic staff.

The compensation for nonacademic staff, however, is usually somewhat higher than are salaries of comparable academic appointees. In securing staff for research projects, we have had to meet industrial competition in recruiting, and their status with us is quite comparable to what it would be in industry.

The same general policy applies to graduate students who have part-time staff positions. The nonacademic staff member who wants to take graduate work is limited to one subject per term and he may not present a thesis based upon sponsored research work for which he has received compensation at a higher rate than that available to the academic appointee. In contrast, the regular graduate student who also has an academic appointment as teaching fellow or research assistant receives a lower rate of pay but has full graduate student privileges, including the opportunity to work on sponsored research and use this work for thesis credit, provided of course it has been approved and properly supervised.

Maintenance of these two rates of compensation requires some dexterous tightrope walking, but we have demonstrated, at least to our own satisfaction, that it can be done. In practice, the Division of Industrial Coöperation, which manages the Institute's sponsored research, gives preference to the academic staff when it is recruiting personnel for a contract project, but if the project cannot be staffed from our academic group, appointments from outside the Institute are made in accordance with the policy outlined above. Even though the salary scale may be somewhat lower for the academic staff, the academic appointment with the privileges it carries remains a more desirable appointment.

Related to this general policy is our limitation on supplementary compensation to academic staff members who work on contract research. Here we follow the policy that teaching and other normal academic duties must not be made less attractive than working on contract research. We share fully in the following recommendations of the Committee on Academic Tenure, Professional Service and Responsibility of the Engineering College Administrative Council:

"If equity demands that supplementary compensation should be paid for extra work within an institution, the amount of such additional compensation should not be so high that it tends to reduce the importance of the staff member's regular work and salary, and to place a value on contract research or nonacademic assignment that is high in relation to the value placed on the usual academic duties.

"Care must likewise be exercised to avoid compensation inequities within an institution which result when some staff members, whose field of work may attract outside research, receive large supplementary salary payments while other staff members, in fields of less immediate application, but possessing equal or greater scholarship and professional standing, receive from the institution only their regular salaries. No plan of supplementary compensation should put teaching in an inferior position or tend to divert staff members from their obligations to their students."

In practice, staff members working on sponsored research have enough time released (*Concluded on page 60*)

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(*Concluded from page 31*)

from academic duties to undertake the research. Out of approximately 200 academic staff members working part time on sponsored research, less than 20 are receiving supplementary compensation. Those who receive this extra compensation agree, for the period they receive it, to forego their privilege of engaging in outside consulting.

Other Sponsored Research Policies

Other more detailed tests which are applied to sponsored research at M.I.T. include the following:

(a) Some department or group of departments (or an academic organization such as the Research Laboratory of Electronics) must be willing to accept responsibility for the project and must have available senior staff members who are free and willing to oversee the project. Contract research is thus under the jurisdiction of the academic departments.

(b) It must be possible to staff the project in accordance with the Institute's prevailing personnel policies.

(c) It must be possible to staff the project without handicapping the educational program either by overloading the staff or by diverting from the educational program the proper amount of attention and interest.

(d) The project must come within the volume of research (measured in dollars, space, personnel, and required amount of administrative attention) which the Institute can appropriately undertake. It must fit into a balanced over-all program and it must be of sufficient importance and interest to be taken into the Institute.

(e) Final approval of the project rests with the academic dean who has jurisdiction. If the project is borderline and the dean has doubts whether it meets the tests and principles laid down, he will bring it before an administrative committee composed of the president, the vice-president, the dean of engineering, the dean of science, and the director of the Division of Industrial Coöperation.

Reduced to a single statement, these principles say in effect that the consideration, acceptance, and priority of any sponsored research project are governed by the extent to which the proposed activity will carry forward the educational objectives of the Institute. Only under conditions of great emergency will projects be accepted which do not contribute to the advancement of educational objectives or of scientific knowledge or of engineering art. We believe that only by strict adherence to these principles can a large volume of sponsored research be undertaken and still retain the integrity of M.I.T.'s educational program. We believe further, however, that sponsored research can be carried out in conformance with these general principles.

In conclusion I would reiterate that research, aimed at advancement of knowledge or development of its practical applications, is both a method of advancing knowledge and a method of teaching and that it must be both when carried on in collaboration with students. In meeting this educational test our research programs must also help to create that subtle kind of environment where scholarship and creative activity flourish and great minds feel at home. The creation of this environment is a major task of our engineering institutions.