THE APPLIED PHYSICS LABORATORY RESEARCH CENTER

Created in 1942, the APL Research Center has been best known for the wartime development of the proximity fuze. Although applied research is emphasized, its work is based on its fundamental research programs.

By ***Dwight E. Gray***

The atomic bomb, the proximity fuze, and radar frequently have been cited as representing the three most outstanding advances in military science made by the U. S. during World War II. All, of course, are dramatic examples of so-called "practical" developments that would have been impossible without extensive prior fundamental scientific investigation carried out on an open-ended time scale in a research-for-its-own-sake environment. It is appropriate that the laboratory chiefly responsible for the wartime development of one member of the above triad should now be pioneering in the integration of applied and fundamental research within a single organization in a manner designed to produce optimum effectiveness for both. The establishment referred to is the Applied Physics Laboratory of The Johns Hopkins University, where the proximity fuze was developed. This laboratory, located in Silver Spring, Maryland, operates under a contract between the Bureau of Ordnance, U. S. Navy, and the University and for the past several years has been engaged principally in a guided-missile research and development program. An indication of its progress in this field is given by the fact that late in 1951 ground was broken in Pomona, California, for the construction for the Bureau of Ordnance of a multimillion dollar plant in which an APL-developed guided missile will be manufactured. The present discussion, however, is concerned only indirectly with the applied research and development to which most of APL's efforts are devoted. This article deals instead with the organization of and the thinking behind a particular division of the Laboratory called the Research Center.

The Applied Physics Laboratory came into existence in June 1942 and, as indicated above, has been concerned chiefly with the proximity fuze and more recently with guided missiles; this type of applied scientific activity is known at APL as "task" research and will be so designated in this discussion. In April 1947 the Research Center was created as a unit of the Laboratory by Dr. L. R. Hafstad, then director of APL and now director of reactor development for the Atomic Energy Commission. In his "creating" memorandum Dr. Hafstad indicated that the organization of the Research Center should be horizontal and along academic lines without vertical channels of authority; that responsibility for conduct of the technical work should be lodged with the senior staff as individuals reporting only to the chairman of the Center; that classification of the work into scientific disciplines should be made only to delineate areas of technical interest and not to denote lines of authority; and that ultimate goals for the Center should include developing fundamental knowledge, generating opportunities for new tasks, and making it possible for every member of the senior staff to devote some portion of his time to research of his own choosing.

Most of the APL Research Center's evolution to date has occurred under the guidance and direction of Dr. R. E. Gibson, who in April 1948 succeeded Dr. Hafstad as APL director, and of Dr. F. T. McClure who has been chairman of the Center since the same date. Details of the underlying philosophy of present operation can be explained best perhaps by stating first the basic responsibilities that have been established for the Center and then outlining the thinking with regard to each. The responsibilities are:

1. To carry on long-range basic research complementary to present and possible future tasks (where "task" is used in the sense defined previously).
2. To establish the Applied Physics Laboratory as a contributor to fundamental research.
3. To provide an opportunity for research-minded scientists at APL to initiate and participate in fundamental research programs not burdened by rigid time scales.

The first objective listed above takes realistic account of the fact that all applied or task research necessarily rests upon a foundation of fundamental investigation. There are three principal ways in which this responsibility is met in the APL Research Center. One concerns the "research of their own choosing" done by the staff. By building a group whose interests and particular competences are in technical areas related to the Laboratory's task work, a natural selection is achieved in

The Applied Physics Laboratory of The Johns Hopkins University is located at 8621 Georgia Ave., Silver Springs, Md.

the direction of "long-range basic research pertinent to present and possible future tasks". For example, one important group of APL's guided-missile task problems is in the general field of combustion, while few, if any, of its current task interests lie in acoustics. Therefore, Research Center thinking would say that flame spectroscopy is a much more appropriate field for study by the Center than, say, the modes of vibration of oval organ pipes. And, in fact, flame spectroscopy is one of the fields in which the Center is competently staffed and is carrying on fundamental research. It is not anticipated that this particular work will produce results specifically applicable to guided-missile engines by next week, next year or, necessarily, ever. The important consideration is that such research broadens the general basis of understanding in a scientific field in which task work also is under way. This is its main purpose.

The second approach to meeting the initial objective involves basic research applied directly to a task problem. It is not uncommon for a scientist or engineer working on a project in applied research and development to be "stymied" because of a gap in fundamental knowledge. It is conceivable, for example, that engineers working on a particular radio transmission problem might find their progress stopped by a lack of information as to how electromagnetic waves in certain frequency bands behave under some unusually complicated set of conditions. In such a situation, the need for fundamental research in a specific area stems directly from a practical, task problem. The basic investigation will be done best by someone interested primarily in the behavior of electromagnetic waves. It is important, however, that he work in close association with the man whose major interest is obtaining a solution for the radio transmission problem so that each can serve as an adviser to the other and both can be continually aware of the common progress. The APL Research Center type of organization permits and encourages this kind of cooperative effort.

The third kind of task-associated Research Center activity is essentially an extension of the second and may be called the research team approach. It can be applied either to the solution of specific task-generated problems or to the development of information along certain lines in anticipation of foreseen future needs. An actual example of the former is the case of a particular design problem whose solution requires knowledge about certain dynamic relationships at present unknown. The Research Center has assigned two of its top-flight mathematical physicists to make up the basic research half of the team studying this problem; the remaining two members come from the task group itself. The second manner of applying the research team approach is exemplified by a group set up by the Center to "watchdog" new developments in electronics. A considerable number of APL's task interests involve electronics, making it highly important that the Laboratory be constantly on the alert for advances in this field and be ready to adapt new electronic devices, the transistor, for example, to the betterment of its program as rapidly as they become available. The Center's electronics research team has the responsibility of keeping APL up to date in this field. Research team projects usually are long-range and, being task-related, may never produce publishable results. Therefore, team members ordinarily do not devote full time to this activity over any extended period but instead alternate it with other basic studies.

Establishment of APL as a contributor to fundamental research—the second major objective of the Research Center—is closely linked to the first. On the one hand, without such a reputation it would be difficult for a laboratory to maintain a fundamental research staff competent to supplement the task work in the fashion described above. On the other, if the first responsibility is adequately fulfilled, this objective to a considerable extent will follow automatically. Also, however, this second responsibility is important in itself, quite in addition to the specific bonds it has with APL task development. In this respect it may be said to involve in part what Dr. Hafstad has called "putting

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something back into the pot." Every technical program dedicated primarily to applied research and development is indebted in no small measure to previous scientific advances achieved through fundamental research. It is right—and, in the long run, profitable as well—that any organization carrying on a program of this sort devote some "tithe" of its over-all effort to pushing back still farther the frontiers of scientific knowledge.

The third basic responsibility—that of giving the research-minded scientist an opportunity to participate in research programs not limited by rigid time scales—sometimes has been dismissed as merely an employment inducement, higher in class perhaps but not much different in kind from paid moving expenses and two months free rent. However, something very much more important and fundamental than this is involved. As has already been indicated, many applied research and development jobs require a fundamental research approach and such an approach calls for competent, experienced, imaginative research scientists. The environment most conducive to keeping alive in a scientist the broad outlook necessary for good fundamental research is one in which freedom from time scales permits him to give rein to his scientific curiosity and dig deeply into whatever phases of a given problem seem to him interesting and promising. Under conditions of complete and strict adherence to an applied program with rigid deadlines, he either may lose both his ability and his desire to do fundamental research or he may find it necessary to move to another laboratory. In either case, of course, he is effectively lost to the original organization as a fundamental investigator.

Thus far the discussion has been devoted largely to the basic philosophy upon which the APL Research Center rests and according to which its objectives have been defined. To place this phase of the work in its proper perspective volume-wise, something should be said concerning the fraction of APL's total effort which the Research Center represents and the portion of the Center's over-all work which falls within the task-associated categories discussed under the first objective. Regarding the former, the term "tithe" used above in a generic sense can be applied more or less literally in APL's case. Both dollar-wise and technical staff-wise the Research Center effort constitutes approximately one tenth of the total APL activity. If one were to plot cost or percentage of total Research Center work against a correlation factor for "task relatedness", one would obtain roughly a Gaussian distribution with the maximum ordinate representing work in fields closely related to task work.

As one might expect, operation of a research staff on a pattern of varying task integration involves a number of practical problems. Some of these are solved at the employment stage. In other words, scientists who join the Research Center staff do so with the understanding that at any time they may be called upon to assist in the solution of fundamental research aspects of a task problem according to one or another of the plans described previously. Thus, at any given time the total number of individuals engaged in work in the Research Center may include one or more in each of the following categories: (a) full time Research Center scientists doing no task-related work; (b) Research Center people detailed full or part time for a certain period to task-asociated research—either as individuals or as members of research teams; (c) regular task staff scientists spending a fraction, one-fifth for example, of their time in the Center—frequently engaged in research for a graduate degree thesis; (d) regular task staff members temporarily working full time in the Research Center—again frequently on a thesis problem. The numbers of scientists in these several categories, as well as the particular individuals in each, are constantly changing in pace with the varying needs and requirements of the Laboratory's over-all program.

The principal theme of this discussion has been the basis of operation of the APL Research Center and the thinking behind it rather than its actual scientific program. A brief listing of some of the fields of the Center's current activity, however, will give an indication of the scope of its interests. These include studies in basic instrumentation, supersonic and hypersonic aerodynamics, microwaves, flame spectroscopy, low-temperature phenomena, characteristics of particular materials, mass spectrometry, high-pressure effects, and others. An extensive program of upper atmosphere research was carried on for several years in connection with firings of high-altitude rockets and gave data at altitudes in excess of 70 miles. Problems investigated in this program included cosmic rays, earth's magnetic field, ultraviolet spectrum of the sun, and high-altitude photography. Photographs of the earth taken in connection with the last-named study received nation-wide general publication some two and a half years ago.

Publications of Research Center staff members have been averaging some 20 papers per year exclusive of those read at professional society meetings. Journals in which these have appeared include most of the publications of the American Institute of Physics; professional periodicals in the fields of astrophysics, chemistry, geophysics and photography; and general scientific journals like *Science* and *Nature*.

In summary, one may say that the Applied Physics Laboratory and The Johns Hopkins University, through the APL Research Center, are combining a fundamental research operation with the applied program which is the Laboratory's chief business in a manner which they believe is proving beneficial to both. The scientist interested chiefly in basic research is brought into contact with applied problems whose fields of application, experience is showing, can be of real interest and challenge to him. On the other hand, the objective, skeptical attitude of the fundamental research worker and his method of approach to problems can have a highly stimulating effect upon the applied scientist in sharpening up his thinking and helping him avoid the pitfalls of too-quick conclusions based on insufficient evidence. The combination shows promise of great mutual advantage to all concerned.