The Key Role of a Mission-Oriented Agency's Scientific Research Activities

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William J. Price

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William J. Price *

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I am very pleased to participate in this Symposium on science and technology interaction. I consider the subject to be both important and timely.

Clearly the continual expansion in knowledge and its proper utilization are matters of utmost importance. Currently we are in a period of the most rapid change in history, which in a large degree is both caused and supported by this expansion. However, our understanding of the processes by which science and technology interact to affect this expansion is not commensurate with its importance to society.

The topic is timely, especially because of its special relevance to the current debate on science policy. Discussions leading to improved understanding of science-technology interactions can help optimize decisions on the nature and amount of both science and technology required to best serve society.

Scientific research is typically packaged in terms of scientific disciplines, while society's problems almost always appear in other forms (1). It is generally recognized that engineers and other technologists must always play a primary role in the required communication. The role of the scientific community is not recognized or understood nearly as fully.

The idea that "good" science must be "pure" academic research where the concept of purity implies conscious disengagement from utility is an indication of the need for further understanding. Even though this disengagement is neither necessary nor nearly as widespread as many seem to believe (see for example Medawar's excellent discussion (2)

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which helps remove this myth), the fact that the idea is brought up frequently underlines the need for additional attention to the scientist's part of the dialogue with technology.

The science-oriented activity in a mission-oriented organization has an important role to play in assuring good communication, inasmuch as it can help optimize the scientist's part of this dialogue. This is a central role of AFOSR for the Air Force, of similar science-oriented activities in other mission-oriented agencies, and of corporate research laboratories for large industrial corporations. This role and the other important functions of science-oriented activities in support of mission-oriented organizations is discussed in a growing body of recent literature (3-9).

The importance generally attached to the support of scientific research by mission-oriented agencies is underlined by the fact that about 85% of all Federal funds supporting university research originate with these agencies. There are, of course, great strengths in the current methods of Federal funding and many seek to maintain similar patterns in the future including the feature that the bulk of the university funds accrue from mission-oriented agencies. It is particularly interesting to note that Sir Gordon Sutherland (10), recognizing the great value of the U.S. system both to the agencies and the universities, has suggested that Britain adopt the system of university support by mission-oriented agencies.

Some persons have raised concerns about the extensive support of university research by mission-oriented agencies. Handler (11) sees a basic incompatibility between university purposes and the requirements for success in mission-oriented research. Therefore he proposes that the bulk of the funds for academic research come from NSF and NIH. DuBridge (12), although he sees nothing basically wrong with the whole picture of U. S. support of science in recent years (including the fact that most of the Federal funds for that purpose accrue from government expenditures aimed at other national goals), calls for an increase in NSF vis-a-vis the mission-oriented agencies because of the current prevalence of short range pressures on mission-oriented agencies which tend to be incompatible with the support of university research. Those who quoted (13) the first interim report of Project Hindsight concerning the small contribution of university research to weapons system development, without critical commentary with regard to the applicability of the Hindsight methodology for evaluating the contribution of such research, in effect have supported concerns about the propriety of the support of university research by mission-oriented agencies.

I believe that the concerns described above and other similar concerns are not valid when the scientific research activities of mission-oriented agencies serve their proper roles -- the roles which have been generally served in the past and which should be nourished in the future. In this paper, I seek to present further information about these research activities to help assure that they are properly evaluated in the current debates. This is a particularly fitting forum from which to attempt this because the interaction of science and technology comes into the discussion in such a central way.

The following discussion draws extensively on Air Force research experience; further, it deals primarily with the university support program. Notwithstanding, I believe that many of the observations which I make apply equally well to the research programs of other mission-oriented agencies and at least in some respects to Federal support of scientific research in industry and government laboratories.

AFOSR Organizational and Historical Considerations

The Air Force Office of Scientific Research is a part of the Office of Aerospace Research, a Separate Operating Command of the Air Force with over-all responsibility for the Air Force's corporate research activity. OAR has a budget of approximately $90 million annually for research. AFOSR, with a budget of approximately $40 million, is responsible for a research program that is conducted by contracts and grants. Other major activities of OAR are the AF Cambridge Research Laboratories and the Aerospace Research Laboratories, both in-house laboratories with associated contract programs.

The systems development responsibilities in the Air Force rest in the Air Force Systems Command. AFSC has an annual budget of over $3 billion for research, development, testing engineering. This organization conducts a great variety of applied research, exploratory development, advanced technology, and systems engineering programs.

The AFOSR program includes about 1,000 separate research investigations at about 200 universities, industries and other research organizations. The research is selected for support from unsolicited proposals. The selection is made by AFOSR program managers on the basis of the suitability of the proposed research to the program for which they are responsible and the scientific quality of the work. Research is supported in chemistry, mathematics, electronics, solid mechanics, aeromechanics, energy conversion, general physics, nuclear physics, solid state physics, astronomy-astrophysics, and the behavioral, biological and information sciences. Interdisciplinary fields are also supported as the need arises.

AFSC, especially through its Research and Technology Division, is also concerned with science, particularly applied science. In fact, the amount of money which AFSC spends in the Nation's colleges and universities through contracts to broadly support technology objectives is somewhat larger than the OAR expenditure through contracts and grants to perform the Air Force corporate research function.

The concept leading to AFOSR was set forth in 1949 by the Ridenour Report, a study by a special committee on the Air Force Scientific Advisory Board. The study pointed out that the Air Force research and development could not be maintained at the highest level of competence without being closely associated with the general research efforts of the Nation's universities. To accomplish this association it recommended that a fraction of the R&D budget of the Air Force should be consistently assigned to contracts with educational institutions for research in broad general fields on problems which, without being directed toward definite applications, are of definite interest to the Air Force. In 1955 AFOSR was established as a separate operating entity, having functioned as a staff agency under the name Office of Scientific Research (OSR) for the previous four years.

Recently we have devoted substantial effort to historical-type studies of AFOSR. These studies, which included a survey conducted by contacting a group of previously supported AFOSR principal investigators and other knowledgeable persons to obtain additional information on the utilization of results of the AFOSR research programs, have been worthwhile inasmuch as they have provided us a large increase in specific information showing how the Air Force has benefited from the AFOSR program. Perhaps even more important, these studies have increased our knowledge of the interaction between science and technology and concurrently have aided us in bringing our role into sharper focus.

We are impressed by both the large number and great variety of the AFOSR accomplishments that can be identified as important contributions to the Air Force. Our success in finding utilization through this study shows us that a large amount of additional specifics could be accumulated if necessary.

I shall only touch on some of the highlights of AFOSR accomplishments as a background for the following discussion. Another publication, just released, includes a detailed account of these accomplishments, along with a discussion of the current program and the ongoing role of AFOSR (14).

We find that the AFOSR has helped colonize many important scientific areas which have turned out to have special relevance to the Air Force, inasmuch as they are generally recognized as underlying important Air Force applications. Colonizing may be described as increasing the chance of important discovery in an area by "raising the temperature" of the world's scientific activity in that field. Through judicious support of phenomena-oriented research and other activities such as symposia, the Air Force research support, amplified by that supported by non-Air Force funds, has affected very significantly the rate of development of important scientific areas -- hypersonic phenomena, including hypersonic facilities, magnetic resonance spectroscopy, optimum control theory, visual perception, mass transfer cooling, information theory and many others.

We also find that AFOSR is playing an important role in technical education. At any given time our research program is providing at least partial support for the doctoral research of more than 1,000 graduate students. The over-all importance of this support is quite substantial but hard to measure; however, it can be appreciated by recognizing that these students are among the top strata of the Nation's graduate students and they are receiving their education in areas particularly relevant to the DoD. Many have gone on to work in Air Force contractor or in-house activities, equipped with knowledge and skills particularly pertinent to their work because of the previous Air Force association.

We also find that we can identify many specific examples where AFOSR supported phenomena-oriented research has provided important support of Air Force weapons acquisition programs at all phases of the research, development, and engineering cycle. We find this input through new or improved manufacturing techniques, design techniques, instrumentation, and weapons systems component concepts, to mention a few cases. The MAB study (15) on research-engineering interaction has also noted a similar diversity in the types of important interactions occurring between science and utilization. The diverse nature of the interactions are also brought out by Morton's model of the innovative process as a complex feedback-type system (16), and Piore's presentation at this Symposium (17).

We also find that many scientists supported by AFOSR are consulting for the DoD contractor and in-house research and development activities. In a very real sense, AFOSR support helps these persons achieve and maintain their expertise while they contribute direct practical help to the DoD.

Finally, it is important to note that the AFOSR program has provided research support for scientists who are among the leaders of their respective disciplines (see for example the current program listing (14) and that the research results have often been among the most important in their fields (see the evaluation of AFOSR research using citation indexing (14).

Interaction of Science and Technology and the Role of AFOSR

We find that it is helpful, both in describing the role of AFOSR and in discussing the interaction between science and technology (18), to divide research and development activity into two broad categories -- phenomena-oriented science and technology -- as illustrated in Figure 1. In technology creative efforts are primarily concerned with synthesis, that is, integration of previously existing knowledge components into operational capability -- for example, systems, devices, processes, methods, and materials. In contrast, phenomena-oriented science is more heavily concerned with the origins of the knowledge components themselves.

Notice in the Figure that both applied science and engineering development are classified as parts of technology. Applied science is so named because its goal is some sort of application of scientific principles. Thus the name comes from the goal. A phenomena-oriented scientist concerns himself with the elucidation of natural phenomena. Thus his goal is the study of phenomena, and consequently, it is reasonable to call his activity "phenomena-oriented science."

As new phenomena are understood, this new knowledge is made available to the scientific and technological communities in many ways. However, it is important to note that the new information becomes known by the peer group in the world scientific community much sooner than it is known by other groups, particularly those associated primarily with technology utilization. Important new knowledge, such as that being accumulated in the scientific fields that AFOSR is helping to colonize, is known to members of the "invisible college" -- that is, those researchers active in the particular segment of the research front, well in advance of any formal written publication. Thus new science may forge ahead, relatively independent of an ambient technology.

Similarly, technology usually feeds upon technology, in the presence of an ambient science. It has become increasingly clear, especially to the historians of science, that technology events are usually initiated within technology. This means that usually it is difficult to establish a unique correlation between a technology advance and one within phenomena-oriented science. One well-known exception is nuclear power, and its origin in the discovery of nuclear fission. Our study shows that one does not usually find a phenomena-oriented research result producing a new and unexpected opportunity which then stimulates a new engineering opportunity (This observation is consistent with those of other recent studies on science and technology interaction (15 - 21). Instead, we find phenomena-oriented research supporting technology in many other important ways, and thus in a real sense making the advances possible.

Thus the gross picture is that technology usually feeds upon technology and phenomena-oriented science usually feeds upon phenomena-oriented science. However, at the same time we find that there is a strong, important interaction (almost a symbiosis) between the two spheres of activity as symbolized by the overlap in the Figure. When one looks deeper (14 - 28) one finds many possible important avenues of interplay between science and technology. Some of these are actively utilized; others need to be further developed.

The nature of this interface is dynamic, varying greatly among different science-technology pairs and with time for a given technology. Industries such as communications, computers, and instruments are much more closely coupled to science than are the railroad and agricultural equipment industries, for example, and transistor technology was much more closely coupled to solid state physics fifteen years ago than it is today.

Further indication of the changing nature of the interface is the suggestion (22) that even though historical studies show two spheres of activity, today the boundaries between science and technology are becoming blurred in many areas of endeavor.

It is found that interactions leading to utilization of phenomena-oriented research are usually initiated by persons who, having the urgent need for knowledge, search for the solution through prior research. The scientists who are consulted also play a very key role on their side of the dialogue, providing knowledge and interpretation from their field.

The fact that new knowledge originating in phenomena-oriented research often has implicit in it important new opportunities for exploitation suggests that when these can be recognized on the research side, great advantages, particularly in timing, can be realized. This appears to be an important area for increased attention by phenomena-oriented research activities toward the end that the initiative can be successfully taken by the scientist more frequently, even though there is some serious question of the value of a solution looking for a problem in the over-all scheme of things.

Our conclusion from these studies is that the conventional picture, which emphasizes a process with unique scientific events being followed in an orderly manner by applied research, development, etc., is usually not borne out. Since that picture appears to be the exception rather than the rule, it is misleading to attempt to elucidate the contribution of phenomena-oriented science by studying this process primarily. In fact, the failure to observe a large number of such cases could lead to a non-objective backlash in which the real (and very important) process involving the flow of an immense number of items of information across the technology-science interface is not recognized.

Any study, for example, of a series of weapons systems aimed at isolating the points of origin, such as identifying key events, will often reveal them to lie within technology (20). A dangerous conclusion which might be drawn from such results is that science (especially current science) is of little help in the development of weapon systems. Actually, what our studies show is that current or relatively recent science is exceedingly important to the development process.

This importance is not so much from the point of view of origin. Rather, there is continuous support in the form of many useful items of information, and particularly in the form of an ever growing sophistication in handling technological problems. This sophistication is made possible by the increased understanding of the phenomena involved and the increased educational level of scientists and engineers.

It is this continuous support which should be the primary object of study rather than the question of origin, when the impact of scientific research is to be evaluated. Recent literature contains numerous comments on the impact of scientific research which generally support this point of view (17, 21 - 28).

Similarly, it would be a mistake to try to have a large fraction of the DoD phenomena-oriented research programs arranged to support specified technology goals, such as the exploratory development projects of the DoD. This type of programming will not work out since its success depends on direct, rather simple relationships between the science program and the technology which do not exist. For example, if the Air Force were to use primarily this type of programming looking back from technology needs toward science, it would end up with more applied science (or technology, in terms of this model). While this type of activity would be very valuable, it would simply be adding to the excellent applied research programs already being conducted by the Research and Technology Division and others, and AFOSR would not be performing its assigned mission. Rather, the role of AFOSR is to capitalize on its strong identity with phenomena-oriented research to bring a new type of capability to the Air Force research and development activities, thus complementing the many excellent technology activities.

This knowledge of the interaction between science and technology provides guidance for the mission emphasis of AFOSR. AFOSR can be visualized as an activity which, because it incorporates intimate involvement with both the scientific community and the Air Force, can help provide an effective interface between these two communities. AFOSR has good ability to attract the interest of the world's top scientific talent, since it is a science-oriented organization with a well-established reputation in the scientific community as a good research agency with which to work. At the same time the AFOSR staff members have the organizational position, and a growing body of experience and techniques for carrying on an effective dialogue with the Air Force technology community.

In providing this interface, AFOSR engages in two types of activities. The first main function is to support high-quality scientific research chosen because of particular interests of the Air Force. We pursue this support in a manner calculated to colonize scientific activities of special importance to the Air Force. The selection of these areas may be motivated either by seeking to pioneer new fields of science holding out high promise for generating the new knowledge from which new technologies or new operational possibilities may evolve or it may be motivated by helping various development or other user groups solve certain difficult classes of important problems by providing a fuller understanding of the phenomena behind them.

The second function is to help provide communication between the scientific community and the Air Force. This is a two-way communication -- needs to the research program and scientific information to the user. The AFOSR project scientists play the key role in this communication or coupling activity. In addition, part of what we purchase through contracts and grants is primarily designed to provide communication. This part refers not only to the symposia we sponsor, but to the connecting-type research which allows us to keep abreast of a variety of scientific areas largely supported by other agencies, but nevertheless important to the Air Force because of rapidly emerging scientific developments.

Specific Areas for Improved Interaction Between Science and Technology

The preceding material provides the context for highlighting areas of improved interaction between science and technology. In summary, my proposition is that, for many important aspects of science and technology interaction, it is essential to recognize that there are two communities -- phenomena-oriented science and technology -- which, although they interact with each other in many effective ways, nevertheless have separate identities. Further, the existence of these two communities leads to a key role and special challenge for organizations such as AFOSR in bringing about improved interaction.

I believe that there is quite considerable potential interest within each community for improved interaction. However, this improved dialogue can often be cultivated best by recognizing the needs and strengths of each community. It is particularly important to build a growing dialogue that recognizes the individuality of each partner.

It is inevitable that these communities will often be organizationally and geographically separated. Further, they usually will lack active emotional identity with a common purpose. Nevertheless, there are many situations where the merging of the two communities by organizational fiat or otherwise would have a dampening effect on communication rather than the intended improvement.

The continued existence of a corporate research function, OAR, may be considered as concrete evidence that the Air Force recognizes the importance of a viable relationship between the scientific and technology communities which allows for the continuing strength and identity of each. OAR provides bridges between the two communities without perturbing unduly the nature of either. This does not argue against the importance to the Air Force of organizations such as in-house and industrial research and development laboratories which incorporate a continuous spectrum from operational requirements to fundamental research. Rather, it says that both types of Air Force involvement with science are essential.

AFOSR meets two special challenges of a continuing nature as it helps serve this interface function. One is the choosing of the appropriate areas in which to support research -- the planning function. The other is helping improve the dialogue between the scientific and technological communities -- the coupling function.

Planning Phenomena-Oriented Research in AFOSR.

At AFOSR we are giving a growing amount of attention to the planning process (29). We believe it is important to do so because the selection of a long-range research program for a mission-oriented organization is a difficult matter for which few guidelines exist, and because the matter of scientific choice is growing rapidly in importance in discussions of national R&D policy (30, 31).*

*The application of the proper planning procedures by AFOSR and other similar activities results in a scientific research program tailored to the needs of each agency. At the same time, when considered as a group, these several research agencies provide support for a great variety of scientific research on the forefront of knowledge. Admittedly, there are many difficulties in these planning procedures, but I know of no other method of simultaneously optimizing the support of high quality science and the solution of society's problems that can approach this in effectiveness.

There are, of course, special planning considerations appropriate for AFOSR and those other research agencies that support a mission-oriented organization. On the one hand, a proper planning procedure brings about choices of broad scientific fields, and of specific work efforts within these fields, such that the scientific research program has a "center of gravity of interest" which meets the needs of the agency it supports. At the same time, the distribution must not be restricted by too narrow a definition of relevance. It must be recognized that some areas of science have special importance for several (perhaps all) of the mission-oriented organizations and that support of these areas by more than one research agency can be important both to provide these organizations communication with the fields and to assure that there is adequate support in these vital areas. Further, the distribution must attempt to recognize both the uncertainties in our knowledge of the scientific results which will be obtained and, even more so, the unexpected avenues of utilization of new scientific findings and therefore the unexpected relevance to the mission of the agency.

Inputs appropriate for consideration in planning the AFOSR research program come to us in many ways, both from within the DoD and from the external scientific community. They come through organizational channels and, most important, they come through the many essential activities of the AFOSR Program Managers.

Information about the long range needs of the Air Force comes to us from top management. The Secretary of Defense and of the Air Force, the Chief of Staff of the AF, and others make speeches and also provide various internal documents.

We receive important guidance from AFSC. Two examples are the AFSC Planning Activity Report and the Technical Objective Document. The latter, for example, sets forth the AF interest in each of the thirty-eight technical areas.

Inasmuch as we know that it is just as misleading to expect a neat flow of research needs from technology as it is to expect a smooth flow of research results into use, we also look beyond AFSC for requirements. For example, our interests include activities in support of military assistance programs, personnel management and training, logistics, and other needs which we find arising from other parts of the Air Force.

Using these various sources of information, we have developed a list of technology areas to be considered in assessing the relevance of research. The relevance is studied with the aid of a large matrix showing the relationship of the technology list to a similarly detailed list of the scientific areas.

The obtaining of the above information is the responsibility of line management and their supporting staffs. In parallel to these activities there is the continual concern for planning at the individual program manager level.

An AFOSR program manager typically has about twenty active contracts and a million dollar annual budget. Each program manager is responsible for one or two subareas; surface physics of solids, control theory, and structural mechanics are typical subareas.

Each program manager must engage in a variety of activities -- both professional and managerial. The way in which he distributes his time is important, so, as in other similar activities, the qualifications and motivation of the scientific staff are matters of utmost importance.

It is clear that the program manager must have a personal knowledge of the emerging opportunities of science, as discussed later.

It is also very important that he have appropriate meaningful personal contacts with those persons throughout the Air Force interested, or most likely to be interested, in the research program for which he is responsible. Here a lot of personal contacts need to be established and maintained through visits, correspondence, special reports, program reviews, participation in joint task groups, etc. A personnel policy which encourages transfers between other parts of the Air Force R&D organization and AFOSR is very helpful in developing properly qualified program managers.

There are several techniques which the individual program managers or groups of program managers have found particularly useful in planning. Let me quickly outline a few of these.

We just sponsored a workshop on Fundamental Problems of Future Aerospace Structures in which the Franklin Institute and AFOSR brought together fifteen key engineers from diversified aerospace industries to present their views of research needs in structures.

The analysis (32) of the material presented at this workshop is an important input to the planning of our solid mechanics program.

During the last several months we have held a seminar on long range research required to support limited conflict. The primary purpose of this series, which consisted of a wide variety of speakers having intimate knowledge of limited conflict problems, was to increase the sophistication of AFOSR staff members in selecting appropriate long range research problems to support that AF mission.

In our combustion dynamics program we run an annual meeting of all of our contractors, along with representatives from the AF R&D organizations. At this symposium contractors present their research results and the AF representatives present research problems which they see.

Another fruitful technique is in-house advisory committees. Carefully selected members from throughout the Air Force technology community meet on a semiannual or annual basis with groups of individual program managers.

Other significant examples of special techniques which I will simply mention are state-of-the-art reviews; participation in ad hoc studies of research and technology utilization for operational needs; and participation in interagency coordination groups such as the Interagency Chemical Rocket Propulsion Group made up of research and development program managers.

The third absolutely essential input for our planning is current information on the continually emerging opportunities for scientific research. Comprehensive studies on the opportunities and needs of science such as the series of subject matter reports prepared under the auspices of the NAS Committee on Science and Public Policy are important inputs. Further, our nine research evaluation groups, one for each of our principal scientific areas, and the Scientific Advisory Group for OAR, which all together include approximately one hundred of the Nation's leading scientists, provide fruitful guidance more specifically tailored for our needs. We also have special studies of various types, such as the chemistry study currently being run for us by the NAS-NRC.

The most vital source of planning information is each AFOSR project scientist's current knowledge of the research area for which he is responsible. He is in an ideal position to be knowledgeable of the emerging fields of science because he continually receives unsolicited proposals from scientists seeking support. The originators of the 2,000 formal proposals and several thousand informal proposals which AFOSR receives each year are ready, willing and able to provide this education to the AFOSR staff. This activity supplements in a very effective way the other professional activities, including sabbaticals, by which the AFOSR project scientists seek to be knowledgeable of the emerging fields of science.

Working with the six managers of the principal scientific directorates, my immediate staff office in charge of planning, and other key AFOSR program managers, I am involved in an essentially continuous dialogue relative to the balance of our activities. Once a year Headquarters OAR calls us and our counterparts from the other parts of OAR together to formulate the OAR Five-Year Plan. Also present are selected members from Air Force organizations using research. This Plan is a comprehensive document which sets forth the specific scientific areas in which it is felt research should be supported by OAR.

The OAR Plan, which we have helped formulate, becomes the guidance which we receive from higher headquarters. It is revised annually in order to keep it viable in terms of responding to new scientific opportunities or to improved understanding of future AF needs for research.

In attempting to maximize the contributions of our phenomena-oriented research program to the over-all mission of the Air Force, we are faced with many choices. We, of course, have no magic formula by which to do our planning and we suspect that none will ever be found. We do believe, though, that searching for answers to these all-important questions in responsible and intelligent ways further optimizes the contribution of our activities. While scientific excellence is always a prime consideration in what we support, we are bringing the relevance and other considerations into play in many ways and we continue to search out additional means to further improve our effectiveness in this area.

AFOSR Coupling Activities

In our coupling function we seek to help bring new knowledge and understanding from world science to Air Force technology on a timely basis and also to provide the appropriate feedback from future operational requirements to the scientific community; in other words, we seek to support and improve the dialogue which exists between the scientific community and the technological community responsible for future AF capabilities.

Coupling occupies all parts of AFOSR to some degree. The AFOSR Directors and myself concern ourselves with methodology, particularly seeking to place management emphasis on those techniques which hold promise for improved effectiveness and efficiency. The individual AFOSR Program Managers are the primary focal points for coupling in that they work directly with their counterparts in both the scientific community and other parts of the AF. We also maintain an AFOSR Research Communications Office which provides the AFOSR Directors and Program Managers staff support for both the planning and coupling functions. These various coupling activities have been described in detail elsewhere (33).

We find the coupling function to be both challenging and difficult. Much of the challenge is associated with its open-ended nature, both from the standpoint of the need which seems to exist and the large variety of opportunities open for exploitation. However, the bringing about of improved coupling usually requires a high degree of professional competence and ingenuity. This difficulty is due to the nature of the communication that is required. It is also due in part to the inherent difficulty of improving coupling mechanisms which in many respects are already operating reasonably well.

In coupling, as in planning, it is very important for an AFOSR Program Manager to develop and keep current contacts with counterparts in the Air Force applied research-exploratory development community. Many of the planning activities which are described above also serve the coupling function so this present discussion can be briefer.

Coupling also requires the AFOSR Program Manager to keep in close touch with scientific research activities. This latter interface is generally the easiest one to maintain because the AFOSR organization matches well with the subject matter fields in which phenomena-oriented scientific research is usually accomplished, and because we have direct connections with many leaders in the scientific fields through our contracts and grant . It is important to note that this interface provides potential communication not only with the research activities we support, but what is often more important, it can help bring to the AF knowledge and understanding from the much broader area of world science with which the scientists supported by AFOSR are in intimate contact.

AFOSR has always sought to encourage the communication methods of the scientific and technology communities which develop naturally in the course of professional activities. We have always believed it important to provide liberal allowances for travel to professional meetings and similar activities. We have vigorously supported publication of research results in the open literature (without previous review, I might add); for example, we have devoted quite considerable effort to this issue within the DoD during the last two years, helping keep this important policy on track in the face of very serious counterforces. We have provided financial support to professional journals when this was required to bring these journals to a self-supporting basis in a timely manner. Included were Applied Mechanics Review, Physics of Fluids, and Mathematical Reviews. We have provided help to professional societies including the Society of Industrial and Applied Mathematics and the Military Operations Research Society. We have helped specialized abstracting services, such as International Aerospace Abstracts and Semiconductor Abstracts, to get started. We support over fifty specialized symposia each year; many of these result in proceedings published on a timely basis.

We have supported the preparation of a large number of books designed to consolidate knowledge in a field and pass it on to others. We have been concerned particularly with those books of use to practicing scientists and engineers, which could not or would not have been written without our initiative and/or support. The AFOSR Directorate of Mathematics alone has supported 81 volumes in the last 12 years.

We have also helped pioneer new types of formalized information exchange mechanisms, including the Bioscience Information Exchange (the predecessor of the Science Information Exchange) and the computerized management control data systems in use by the DoD and currently being adopted by other agencies.

Some of our most meaningful coupling activities are those which include the personal involvement of the research scientists under AFOSR support. The following are a few examples: trips to Air Force installations to perform consulting services; extended stays in Air Force laboratories; membership on ad hoc groups to study feasibility of various exploratory development programs; performance of research for technology-oriented organizations complementing the AFOSR research; state-of-the-art reviews, either oral or written; special purpose symposia which are specifically designed to bring technologists and scientists together; special lecture tours; performance of feasibility studies on research phenomena to package them in a form more likely to be useful; and direct consultation with the aerospace industries.

Rather frequently I hear it stated or at least implied that university scientists generally insist on doing pure science and to this end resist or at least resent any involvement in society's problems. My four years of experience in the AFOSR coupling program supports a diametrically opposed point of view. I find that the vast majority of scientists find significant satisfaction and stimulation in making these direct contributions to the DoD programs, in addition to the important, although often less direct, inputs which they are making through their research results.

Project and Programmatic Methods of Support

I need to discuss briefly our methods of administering the extramural university contract and grant program with particular reference to programmatic and project methods of support since this bears directly on the topic of this Symposium.

Both project and programmatic methods of support have the same objectives; each provides the administrative and managerial vehicle through which research programs of interest to the AF are conducted in colleges and universities. The two methods differ in two ways, primarily, the selection of the individual work efforts which make up the program, and the geographical location of the individual work efforts.

In the project method of support the AF Program Manager has the responsibility for selecting the individual projects or work efforts which, taken together, constitute the DoD research program in the particular program area; in the programmatic support, the selection of the individual work efforts is largely delegated to the university program director.

With the programmatic method of support, all of the work efforts in a given program are generally carried out at one university, while when the project method is used, the DoD program in a given program area is carried out by projects at a number of universities.

In the project method of support as used by AFOSR, each contract or grant is an integral part of some larger program which is the responsibility of an AFOSR Program Manager (see previous discussion under planning). The AFOSR Program Manager selects the individual projects from a large number of unsolicited proposals, basing his selection on the potential contribution of the proposed research to his program objectives, the competence of the principal investigator, the uniqueness and importance of the idea proposed, and the advice from his extramural and intramural advisors and consultants. In turn, the principal investigator has the responsibility and necessary flexibility to vary from the specific objectives set forth in his proposal if doing so will help maximize the impact of his research. The Program Manager utilizes a variety of techniques for bringing about effective interaction between the individual principal investigators making up his program and for coupling this program to the needs of the Air Force, as discussed in the previous sections.

In the programmatic method of support a program manager is designated at the university. He has over-all responsibility for the program, including the selection of the individual work efforts which make it up. These university programs may or may not be interdisciplinary. Likewise, they vary in the extent that they include a concern for applied science and technology along with the fundamental science. The local program manager assumes a responsibility for relating his program to the needs of the sponsoring agency(ies), including working with the DoD technology organizations as well as with the responsible AFOSR scientist. The laboratories of the DoD Joint Services Electronics Program (of which our host the Coordinated Science Laboratory is one of the most distinguished) are excellent examples of programmatic funding. Other examples are the ARPA-funded Interdisciplinary Laboratories for materials research and the new programs currently being implemented under the new DoD university support program Project THEMIS.

I am going to almost bypass the obvious and important question of how the two methods of support compare from the standpoint of their contribution to the interaction between science and technology. I'm sidestepping this question because it is too important to treat in the inadequate manner which we would be forced to here. The treatment would be inadequate because the question is too complex to treat quickly and also because much of the information required to evaluate the two methods is not yet available.

The following are some of the complex issues involved in the above question.

-Relative effectiveness of the agency and university program managers in providing the required interfaces with the agency technology.

-Comparison of scientific excellence of work efforts supported by the two methods.

-Extent to which university programs involve spectrum of basic and applied work and interdisciplinary approaches.

-Flexibility -- short term and long term -- considered from both the agency and university standpoint.

-Relative compatibility of the objectives, as well as the administrative procedures, of the two methods of support with the fundamental purposes of the universities.

-Potential for assuring that the universities can make their unique contribution to the DoD technology-scientific community dialogue as compared to contributions of industrial and DoD in-house R&D organizations.

Currently about one-half of the AFOSR work with educational institutions is administered by the project method, one-third by the programmatic method, and the remainder by group-type research agreements which combine the work of more than one senior investigator at an institution into one flexible instrument.

My personal position on the two methods of funding university work is that we should continue to use both methods, doing everything we can to keep each completely viable, and at the same time continue to seek to improve the effectiveness of each method in providing interface between science and technology. At all times we must consider the best interests of both the universities and the DoD, particularly their long-range interests. If at some later date it is clear that the balance in use of the two methods of support should be changed, then we should act accordingly.

In view of the lack of such evidence at the present time, current efforts to make further large increases in the amount of programmatic funding by discontinuing project-type funding to make the funds available should be resisted.

Should Applied Science in Universities be Increased?

We have been asked to consider the improvement of science-technology interaction through increasing the amount of applied science carried on in universities. In dealing with this question, one must first agree on terminology. In this paper I have defined applied science as part of technology -- the search for new products, devices, etc. Consequently my definition points to a negative answer to the question of applied science increase, since clearly technology is not an appropriate activity for major concern by a university. On the other hand, if one uses Ed Teller's definition of applied science (34) as the activity which bridges "pure" science and engineering, one reaches the opposite conclusion. It is not only appropriate, but is is also important that universities be involved in the dialogue between the phenomena-oriented scientific community and the technology community. The growing AFOSR activity in planning and coupling, already described, characterizes our understanding of the nature of the appropriate dialogue.

Except in the case of the medical profession where university hospitals are major instrumentalities for the utilization of medical science and technology, the universities do not provide self-contained organizations with operational missions requiring the support of a science-based technology. Further, the existence of industry and in-house R&D organizations which provide very extensive and capable means for utilization in nearly all fields of interest to the DoD removes both the necessity and desirability of establishing such organizations within universities. Consequently, even though extensive additions of applied science and technology were made to universities, the interface between university science and its utilization would still largely remain external to the university.

The one great advantage I can see in having some applied science in the universities is that its presence helps catalyze vital science-technology interactions elsewhere. Those university scientists who are primarily knowledge-oriented can be aided in their secondary function of seeking to couple science and technology in cooperation with AFOSR or otherwise, by association with colleagues who are doing applied science. For example, I believe that the fact that the Coordinated Science Laboratory on the University of Illinois campus has been concerned over the years at least in part with applied work has had an important impact on the concern with utilization in other parts of the University program. Dean Alpert's paper (35) for this Symposium presents an excellent discussion of the methods and rationale of the programs by which the University of Illinois continues to pioneer in this important activity.

In summary, I believe that the value of applied science in universities is not primarily in providing local interactions by which growing numbers of university scientists can work on the problems of society, but rather that applied science within a university helps catalyze effective dialogue elsewhere. Toward this end, it is important that the DoD continue to support relatively large amounts of applied research motivated by its technology organizations. Currently over one-half of the DoD monies going to college and universities comes from these organizations. These funds certainly should not be allowed to drop as is presently programmed. Nor should it be required to decrease phenomena-oriented university research in order to support applied science, particularly in view of the squeeze on DoD research funds discussed in the next section.

Concerns about Current Trends

Finally, I want to discuss concerns which I have about some current trends in policy and in funding for scientific research which bear directly on the symposium topic. This is a time of many diverse demands on the national budget, and it is no wonder that research budgets and methods for setting priorities for scientific research activities have come under the public spotlight. A redistribution of research support is occurring. Also, there is great concern for utility, shared by most of us at this Symposium. There are, however, indicators that we are in danger of serious maladjustments caused by applying over-corrections or unwise corrections.

In attempting to assure timely utilization of scientific research, while simultaneously being forced to present convincing arguments for budgets to an increasingly diversified audience, research activities may be tempted or even required to put too much emphasis on such factors as the promise of practical advance and geographical distribution. The recent action in which Congress, in taking $12.5 million from scientific research in the FY 68 DoD appropriations bill, designated that this money should be cut from the university research, but not from DoD Project Themis (which has both the geographical distribution feature and a promised relevance which in some respects can be presented more readily) is a concrete part of this trend, which has been building up for some time.

Figure 2 shows the trends in the support of research, both Federal and OAR totals. Since funds available for OAR have not kept up with the increase in the cost of doing research (approximately 6% a year), the total amount of research which we are able to support in the Nation's colleges and universities has dropped somewhat during the last six years. Over the same period the fraction of the total Federal research that is supported by the Air Force and by the DoD as a whole has dropped rapidly. At the same time, increasingly larger amounts of the funds available to us have been used for new programmatically-funded efforts and for special purpose research activities. The overall impact of these trends has been that our capability to maintain a viable interface with the continually emerging new research activities at the forefront of science has decreased markedly. This is particularly telling in our capability for funding outstanding young scientists who are continually appearing in the scientific community.

Over the years beginning with World War II there has come into existence an effective and important working relationship between the DoD and the university research community. For the above, and other related reasons, there is considerable cause for concern that this relationship will be seriously deteriorated if current trends are allowed to continue.

I believe that it is important to this Nation that the effective working relationship between the DoD and the universities be continually strengthened; certainly it should not be allowed to deteriorate. For example, its importance to the interaction of science and technology supports this point of view. The DoD university research program and that of other mission-oriented agencies is also quite important to the universities from the standpoint of obtaining adequate support of scientific research.

Persons in the academic community and in other quarters often support a plan which proposes to continually shift the funding of university research from mission-oriented agencies to the NSF (Incidentally, it should be noted that these same persons often erroneously equate research supported by a mission-oriented agency with applied research; e.g., see Handler's discussion (11). During the years which this plan has been pursued, the university research support by mission-oriented agencies has tended to level off, but adequate compensatory increases in the NSF program have not been forthcoming.

Certainly Congress and other persons responsible for science policy and funding will continue their critical studies for some time. I feel optimistic that these studies will lead to the provision of adequate funds for university research on a continuing basis. However, I believe that Congress is much more likely to understand and support a program which provides good balance between that for science-dependent mission-oriented organizations and that for NSF than it is to provide large increases for the relatively non-utilitarian NSF program.

Those faced with the problem of developing the over-all science policy for the Nation have many complex issues with which to deal. It seems clear that one very fruitful avenue to pursue is the development and presentation of the important role of the scientific research activities of mission-oriented agencies.

Summary

In this paper I have discussed the functions of science-oriented organizations in mission-oriented agencies, using AFOSR as an illustrative example. I ~~have described~~ these organizations as having a key role to play in the interaction between science and technology. By making the proper choices of scientific areas for support and by helping to improve the dialogue between the scientific and the technological communities, these organizations serve a function which is very important to both the agencies which have special responsibilities for solving the problems of society and the university-based scientific community which must provide education and new knowledge. The programs of these organizations bring benefits to both the universities and the agencies which cannot be obtained through agency-supported research that is closely related to short range needs nor through the scientific research supported by other agencies.

My proposition is that the best interests of the Nation will be served by continuing to provide the bulk of the university funds to universities through the scientific research activities of mission-oriented agencies. Arguments against this can be seen to be largely invalid when they are analyzed in light of the proper functions of these organizations. For example, the mismatch between the problems of the mission-oriented agencies and the disciplinary structure of universities is the central reason these organizations are needed, not a cause for shifting their funds to NSF and NIH as Handler suggests (11). Furthermore, when the value of university-based research to an agency is considered in the context of a detailed picture of science-technology interaction, there is satisfactory proof of great value received in the past and expected in the future, not the lack of rationale for the agency expenditure of funds that certain Project Hindsight inspired comments have indicated (13).

When von Karmen was awarded the First National Medal of Science in February 1963, President Kennedy said "I know of no one else who so completely represents all areas involved in this medal -- science, engineering, and education." von Karmen replied "I hope that my work has shown that the college professor is of use." Certainly von Karmen's hope was well founded. However, the science-oriented activities in mission-oriented agencies have an important continuing role to serve in order that the continual expansion in knowledge and its proper utilization will work together to provide optimum benefits to society.

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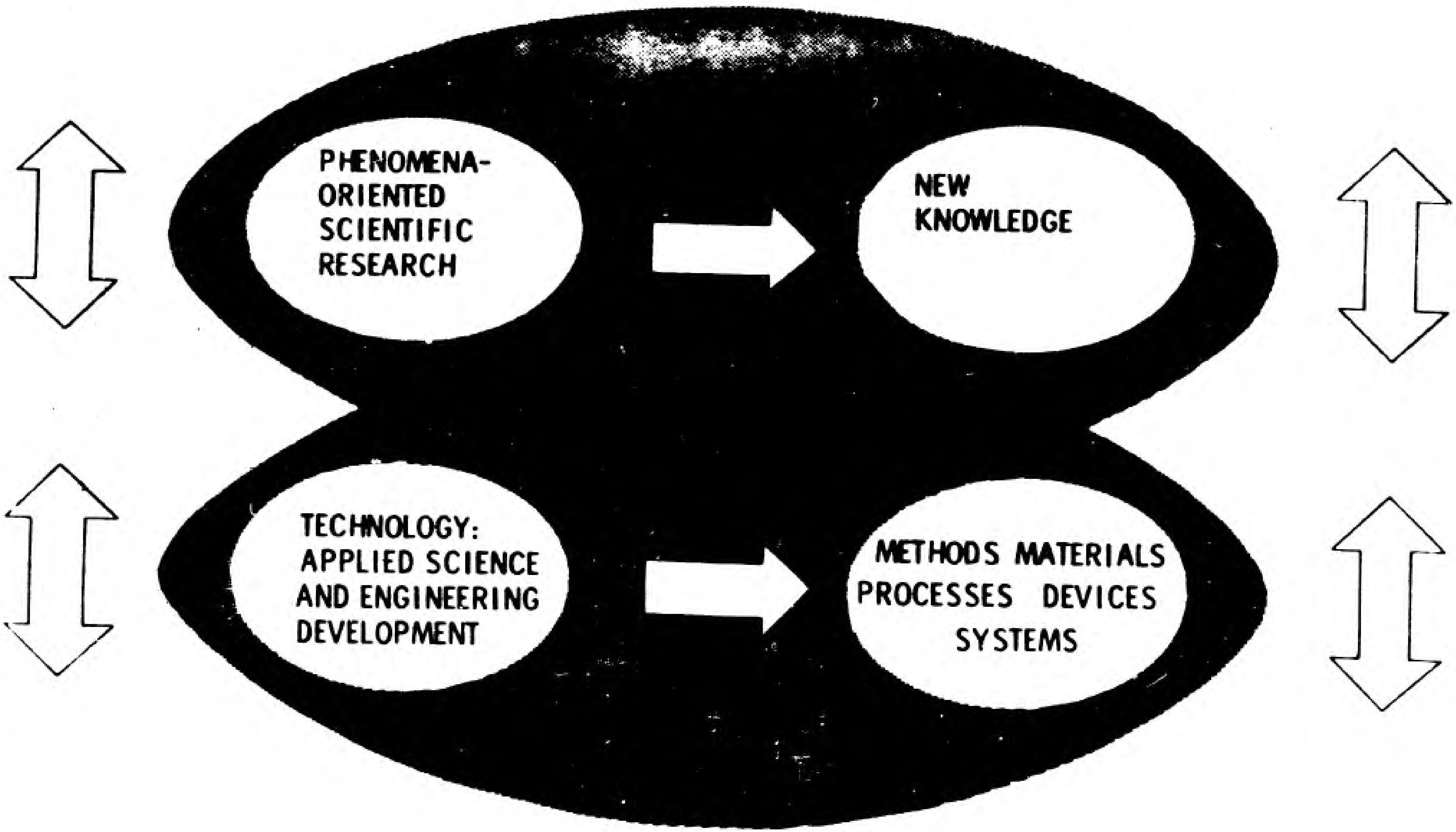
PHENOMENA-
ORIENTED
SCIENTIFIC
RESEARCH
NEW
KNOWLEDGE
TECHNOLOGY:
APPLIED SCIENCE
AND ENGINEERING
DEVELOPMENT
METHODS MATERIALS
PROCESSES DEVICES
SYSTEMS

Figure 1

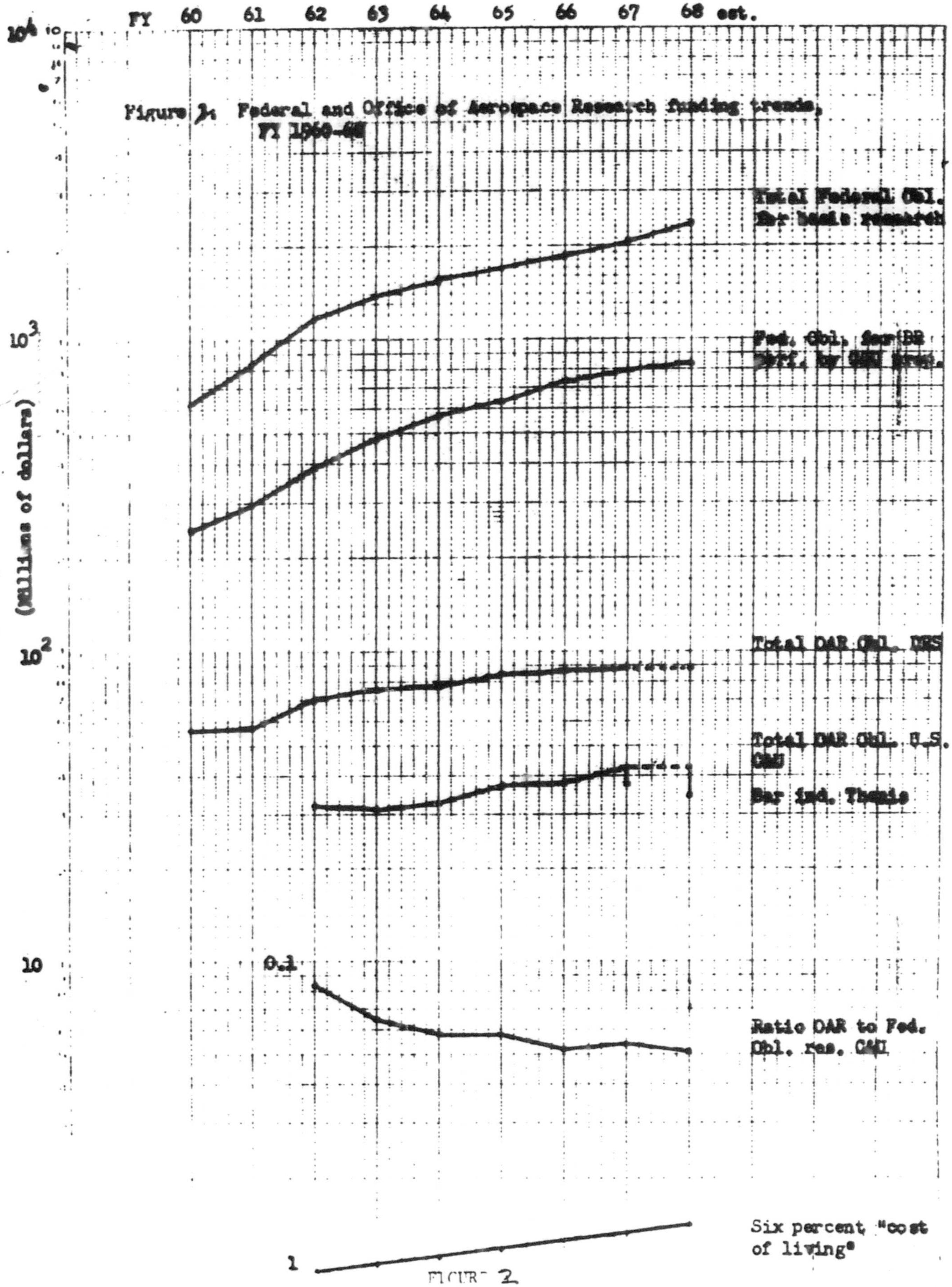

Figure 2. Federal and Office of Aerospace Research funding trends, FY 1960-68

FIGURE 2