

## FEDERAL RESEARCH—STIMULATOR OF PROGRESS

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### INTRODUCTION

Physical and social progress today depend upon the systematic process of research and development. Research, whether sponsored by government or private agencies, can leaven our economy and society. It can have effects spreading far beyond the research act or finding, just as one neutron can trigger a great explosion—but a way must first be found to start the reaction. It is therefore fitting that the Joint Economic Committee of the Congress should devote part of its study of Federal expenditure policy to the topic of research and development. On behalf of my colleagues at Stanford Research Institute, I am happy to take this opportunity to present our views on this subject under the title of "Federal Research—Stimulator of Progress."

It is our view that we cannot live indefinitely in a world where social progress advances arithmetically and technical progress advances geometrically. Because of our belief, this paper presents three main points of view:

1. Research and development have long since proved their unique value in advancing our technical prowess in the realms of defense, industry, and business.
2. Research, under the leavening sponsorship of the Federal Government, can be equally effective in the realms of human relations, social affairs, and other public problems.
3. Research in this Nation must be coordinated and analyzed and its meaning and capabilities profoundly understood if we are to derive from our research and development efforts the full benefits intrinsic to the scientific approach.

First, however, let us define "research" as the term is used in this paper. Most research in industry and government is of an applied character, and it is this applied type of research that is under discussion here. Applied research has a number of distinct facets. In the field of health, for example, applied research may create an antibiotic having specific properties—a tangible material. It may evolve a course of treatment for a particular disability—a method or process. Research may also, however, provide information on the probable consequences of following any of several courses of preventive action—a management aid.

The terms "research" and "development" have become stylish in both private and government circles. The securities analyst, for example, tends to put a premium on the stock of companies that report large research and development budgets. Because of the glamour of the term "research," however, an unfortunate tendency has emerged to label some activities as research which really do not deserve the

name. Some of the criteria that distinguish true research from the activities that masquerade as research are therefore worth mentioning.

Inherent in true research is the use of the scientific method. At the heart of the scientific approach is the analyst's interest not only in what happens, but in how and why it happens. He seeks an understanding of phenomena through certain basic steps:

1. He states the objective of his study as best he can and asks himself the pertinent questions.
2. He makes observations and measurements and records data.
3. He develops trial ideas or "hypotheses" which relate his various observations. In research dealing with policymaking and decision-making, this step requires making a "model" of the operations. The model is an analog, often mathematical, of the real system under study.
4. He devises experiments or other tests to determine relationships among the measured elements of the problem, gathers information to round out the picture, modifies his original hypothesis as necessary, and selects the hypothesis that best expresses the relationships involved.
5. Finally, he applies his refined hypothesis to the problem.

This approach can be used to achieve either of the two principal aims of science or management: (1) To control the phenomenon or operation or (2) to predict future events.

Unless an investigative activity utilizes the scientific approach it cannot fully express the potential of research and it therefore does not properly earn the designation "research."

This paper deals with applied research in the sense just defined. Its domain is applied research, supported or conducted by the United States Federal Government and, more particularly, that segment of the Federal program devoted to nondefense research. The important areas of industrially supported research and governmental defense research are well recognized and are treated herein only for comparison. It is one thesis of this paper that nondefense applied research, under government leadership, can produce a great variety of basic national benefits that can never be attained without conscious and concentrated effort.

To develop our viewpoints we first discuss the place of research and development in the Federal Government today. Of particular interest are current trends and the nature of the research process—what to hope for from research, how research influences the economy, and the significance of attitudes toward research.

That general discussion is followed by a number of illustrations of directions which Federal effort could take to utilize the full potential of research in nondefense areas. It is our purpose to show that many vexing problems of national concern can be made to yield to the research attack, if only the proper approach is selected.

The paper concludes by proposing a plan which gives promise of improving research and development efficiency throughout the Nation. At the same time this plan could give rise to major advances in our understanding of the fundamental capabilities of research as a tool able to help bring about a world more at peace with itself.

## THE PLACE OF FEDERAL RESEARCH

However measured, research and development work supported by the Federal Government is big business—and is growing bigger. About \$3 billion a year, or 4.6 percent of the total Federal budget of some \$65 billion, is currently spent on research and development. It is perhaps more meaningful that the two activities consume roughly 6.4 percent of the amounts spent for the purchase of goods and services—mainly, equipment and payrolls.

*Trends in research and development*

The national defense program absorbs a very large fraction of total research and development expenditures. Of the \$3 billion, about \$2.7 billion is used by the Department of Defense, the Atomic Energy Commission, and the National Advisory Committee for Aeronautics.

Expenditures for defense and for nondefense purposes are increasing at about the same rate. In both fields obligations in 1957 were 2.5 times the figure for 1947, measured in constant dollars. In absolute terms funds obligated for defense research rose from \$712 million in 1947 to \$1,806 million in 1957, again stated in 1947 dollars. On the same basis, nondefense obligations during the decade increased from \$112 million to \$281 million. Appendix I contains details on Federal research and development obligations and expenditures, analyzed in several ways.

It is pertinent to examine the ratio of research expenditure to the value of the product and activity it supports. The goods and services that national defense research affects will, of course, actually be purchased at different times in the future. Nevertheless, the current ratio is revealing. In recent years this ratio has hovered around 5 percent, the 1956 figure being 5.2 percent.

An exactly analogous comparison cannot be made for nondefense research expenditures because much of the research and its products relate to activities outside the governmental sphere. To provide an indication of the relation between defense research activities costs and nondefense research activities costs, nondefense data on Federal research and purchases have been combined with research and products in the private-business field. The research cost to activities value ratio for all nondefense purposes has climbed from about 1.3 percent in 1947 to 1.7 percent in 1956.

The difference between these two ratios for defense and nondefense states that more than three times as much is spent on defense research per unit of product or activity as is spent in the nondefense realm.

Trends within national defense research expenditures are interesting in that the concept of methods research, especially that of research on matters affecting decisions and policies, is taking hold rapidly. Although research on physical problems is still overwhelmingly predominant, the whole field of operations research is receiving much special attention. Many branches of the armed services, together with special groups such as the Rand Corp., Operations Research Office, and Operations Evaluations Group (acting for the Air Force, the Army, and the Navy, respectively), are pressing this aspect of research effort with particular vigor.

Because the Government's present expenditures for nondefense research and development are comparatively so small, trends are more

difficult to isolate. It nevertheless seems reasonable to suppose, in view of the characteristic spreading habit of research methods, that similar trends are active within nondefense research. Certainly they are pronounced in industrial research, and give every indication of becoming more so.

*Research, economics, and society*

It always has been and always will be pertinent to ask what we want for our research dollars.

One classic answer is profit. That answer has motivated and still motivates almost all industrial research. Another answer is national security. That, of course, is why this country spends some 90 percent of its research and development funds on defense research. But there are other answers, too, and they are the answers that constitute the reason for this paper.

Research can be a stimulator of progress, with all that that connotes. Innovation—generated largely through research—is one of the great dynamic forces in an economy. Innovation is not only a matter of providing that human needs are more fully and better fulfilled. It is also a matter that vitally affects the economic health of the complex civilization in which we live. Our whole economic and social structure is such that if we do not continually press forward, we are in serious danger of falling back.

In their impact upon society, innovations are like waves. Once a series of discoveries has been initiated, it finds response in many fields, first those closely associated and then those more remote, until, like ripples in a still pond, everything within reach is touched. A kind of spirit of adventure pervades all endeavors, not alone those of the innovators, but those of business leaders, social leaders, and all other members of the community. In some respects and in some degree, exactly this has been happening in the past few years. In this case, military research and development has provided one of the important originating forces.

We need examine only 1 or 2 of the technical developments started during World War II to see the multiplying effect that research and development can have upon the Nation's technology and economy. Progress in developing fire direction systems for air and naval weapons later led to the electronic computer and to factory automation and control equipment—major businesses today. Improvements in military aircraft and their powerplants led to rapid expansion of the air transportation industry, with its inherent ability to knit the Nation and the countries of the world in to closer and more harmonious communication.

If innovation is a key to economic and social progress, we must ask how innovation is fostered. Any such consideration must take into account the impact of the technological, methodological, or policy-making breakthrough.

Barriers to further progress in a particular field crop up from time to time and advances are slowed until the barriers are penetrated. Once the barrier is penetrated, repercussions often fan out in all directions, leading to gains in a host of allied and distant fields.

The past has seen many such breakthroughs. As a rule they have come about rather gradually and their effects have spread slowly. In recent years we have learned, however, that under pressure of war or

other great need, a breakthrough can be forced much more rapidly than would occur in the natural course of events. The spectacular example of course, is the creation and control of the chain reaction of atomic fission. Other examples can be found in the field of electronics, high-temperature metallurgy, computers, polio vaccines, and mathematical models for decision making in military strategy and tactics.

We must realize that each type of investigation—if appreciable progress is to be made—requires its own appropriate threshold level of activity below which little contribution can be expected. The principle involved is not entirely understood. Nevertheless, comparisons between research activities that yielded spectacular success and those of only mediocre fruitfulness seem to suggest that disappointing results may stem from the project that fails to mount a sufficiently high overall level of effort, no matter how ably staffed and administered. It is conceivable, for instance, that the effort of keeping abreast of current literature in a given field may require the full attention of the project team. Under such circumstances no new contributions can be expected. Such an explanation is certainly no full answer to the problem of evaluating the appropriate level of effort on a project. Until the phenomenon is better understood we can say only that problems differ greatly in the threshold level of effort they require for resolution.

If we identify a critical roadblock, and if we conclude that it must be removed, and if we mount a concerted effort to or greater than the threshold effort required to break through, we usually accomplish valuable results. We always take the calculated risk that the results will not be worth the effort. Nevertheless, whenever means exist for attacking a problem, we may anticipate eventual reward if enough directed effort is put forth. Some attempts will fail; some will be only partly successful; others will achieve triumph.

The significance of the breakthrough principle to the Federal Government is that the Government often is the only agency that can mount an attack that holds promise of success.

By its nature, then, research thrives only in an atmosphere that believes in its widest potentials—in an atmosphere conducive to progress. Through research the group or nation believing in progress will achieve its ends. We must remember, too, that pathfinding research does not operate in a vacuum, but has an infinitude of beneficial side effects. Progress spearheaded by the Federal Government will inevitably lead to far faster progress by State and local agencies, by private enterprise, and even by the initiator, the Federal Government.

#### RESEARCH AND DEVELOPMENT POTENTIAL IN NONDEFENSE FUNCTIONS OF THE FEDERAL GOVERNMENT

We have already seen that nine times as much is spent on defense research as is spent in the nondefense realm. Perhaps nondefense activities, then, represent undeveloped opportunities for useful research, because in them there is more virgin territory untouched by the effect of either an appropriate threshold level of research, or, in some cases, of any research at all. It is the purpose of this section to examine a few of the key nondefense activities in which the Federal Government has an interest, as a means of suggesting research opportunities of unusual promise.

Most of the research supported in the past by Government and private agencies emphasized products and physical phenomena. In the future, however, research on social phenomena can lead to an era of social invention perhaps comparable to the great era of technical innovation we are now witnessing. The results of undertaking research on the large and pressing problems of public policy will be manifested mainly in social adjustments, policy determination, and aids to administrative decision-making. It is likely, however, that some solutions will suggest combinations of equipments and humans into new systems that are more productive or beneficial than any we now know about.

The public problems that illustrate research opportunities in non-defense activities fall under three major groupings of Federal Government interests: (1) National human resources, (2) national material resources and public facilities, and (3) international relations. No attempt is made to group these problems according to responsibilities of departments of the executive branch of the Federal Government. Indeed, in nearly every case the scope of the problem cuts across functional departmental lines. While most of the problems listed in these three groupings are directly related to Federal Government responsibilities, others are only indirectly related. Even in the latter situation a case can be made for Federal expenditures for research to take leadership in promoting the general welfare of the Nation and in sponsoring exploratory and pathfinding efforts which can stimulate activities in the private sector of our economy.

#### *National human resources*

No area is more important to our national welfare than that of human resources—people. Their happiness and their effectiveness are involved. Education is one important domain of human resources. Health, crime, management-labor relations, and racial problems are others, to name a few. All of these are prime subjects for innovative research.

The preservation of our democratic heritage and the development of our human and natural resources are attributable in no small degree to our system of universal education.

Informed citizens agree that education today is confronted with many varied and complex problems resulting from our phenomenal increase in school population, our changing technology, and our new role of leadership in world affairs. The problems center around teaching staffs, curriculum and guidance, organization, and financing. Solutions are not likely to be found without major research studies. It is not easy to say to what extent the Federal Government should finance research on education. It may be sufficient to note that many problems of nationwide importance lack solutions as well as sponsors for adequate research on them.

We need answers to questions about teacher supply; about how we can staff schools and colleges for doubled enrollments when the supply of new teachers is actually declining; about how we can increase or stretch the effectiveness of capable teachers; about how we can finance a scale of teacher compensation that is competitive enough with other professional rewards to reverse the trend away from the teaching profession.

One particular aspect of education and training of paramount concern to the Federal Government directly is the need to determine what competencies will be required of the men and women in the Armed Forces of the future. This problem is a major one in view of the growing technical complexities of military weapons and equipment. Much serious and imaginative study should be directed toward providing competent technical manpower through farsighted education and training.

The Federal Government is the largest single sponsor of medical and health research. In this case the total amount spent for research is less open to criticism than the way expenditures are allocated. For example, despite an annual operating expense of \$900 million for Federal hospitals, little research has been done on ways of making hospitals more efficient.

Crime as a public problem takes a multibillion dollar economic toll. It represents an immeasurable blight in human anguish. Despite heavy spending by all levels of government to prevent and control crime, scarcely any pathfinding research is underway to seek new approaches to corrective and preventive measures. Organized applied research by qualified social scientists and physical scientists could well give rise to social inventions helpful in this national problem.

Another barrier to economic and social progress is the continuing problem of industrial management-labor union relations. The public interest in achieving a greater degree of harmony and equity in these relations is so important that this topic deserves attention in an organized research effort.

In these troubled times of racial integration of schools, our public officials must make decisions and policies without an adequate understanding of the consequences of alternative programs and without a sufficient knowledge of attitudes and how to change them constructively. Despite our past failure to undertake adequate research on this problem, it is still not too late to launch an inquiry into problems of race relations and to gather experimental data from the diverse methods that are being used to comply with the Supreme Court ruling on desegregation of schools.

#### *National material resources and public facilities*

Many problems in managing the Nation's natural resources and the Nation's public facilities are potentially researchable. Research on these topics can guide planning and the allocation of future expenditures.

The field of agriculture illustrates how research activities in industry and Government have cooperated to push productivity to ever-higher levels, in recent years advancing even faster than in manufacturing as a whole. The farm-equipment manufacturers are bringing out better and better machines; the chemical companies are introducing improved fertilizers and insecticides; the Department of Agriculture is developing new strains of animals and plants, new methods of cultivation, new marketing procedures, and new means of helping farmers decide on what to grow and how to utilize the natural resources of the land to the best advantage. As a nation we can be proud of our success in increasing productivity in agriculture, but at the same time we should strive for a better balance that will distribute the remarkably high agricultural output. Research efforts now

should be directed at determining policies which will enable the Nation to reap fully the advantages of increased productivity.

Opportunities for research exist in discovering greater industrial uses of farm products. Here, as in other problems, the Federal Government should try to sponsor research that will stimulate private industry to carry on its own studies of industrial uses of agricultural products.

Water has assumed new importance as a national resource because of rapid regional developments in population, industry, and agriculture. Actual or threatened shortages may endanger the means of many people to make a good living and the growth and economic health of whole regions. A special reason for Federal interest in water and initiative on water research is that the economic units for water supply and use are not coextensive with State boundaries or sometimes even with national boundaries.

There is need to formulate unified policies for entire water basins flexible enough to meet local conditions but clear enough to guide the Congress in such things as judging between competing functional and regional demands for water, means of financing water development, and the proper degree of Federal participation in development and control.

Research is needed especially on means of securing adequate supplies of water of the proper quality for domestic, municipal, industrial, and agricultural uses. Such research must be undertaken in coordination with study of problems in pollution, flood control, hydroelectric generation, navigation, and recreation, including the propagation of fish and wildlife. The research should deal extensively with projections of population and industry growth and with areas yet to be developed. Much more attention is needed on getting the highest economic use out of scarce supplies, better correlation of benefits and costs, and on more equitable financing of improvements by beneficiaries.

The Paley Commission has made a number of constructive suggestions for research and development on materials and energy resources. They need not be repeated here. However, one field for research deserves a high priority, namely, the use of western coals and of certain low-grade mineral deposits. Western coal is an abundant energy resource which seems much nearer to utilization than most others. Even so, its potential is not being realized because of unsolved technical and economic problems centering around getting the coal to market or converting it at the mine or elsewhere into electrical, gas, or liquid energy. The fact that the Army is supporting a modest research effort on these problems indicated the Federal interest in it. The growing dependency of the United States on imported petroleum and the increasing petroleum deficiency of the Western States accent the need for a stepped-up effort. This effort should be coordinated with the research and development on the chemical and industrial uses of coal for other than energy purposes. Since there are many well-financed private enterprises with an interest in research on coal, and which have done major work on it, the Federal Government should focus on leadership and coordination rather than replacing private responsibility, initiative, or financial support.

Technological advances and improved organization of mining and processing industries, accompanied by the ever-growing needs for

minerals of many types, has increased the incentive to discover and improve ways of using mineral deposits which may have been classed as uneconomic in the past. Many deposits were discovered when the circumstances for utilizing them were far less conducive to success than they are today or as they seem to be in the future. Production of copper from low-grade ores, iron from taconite, aluminum and uranium from deposits considered worthless only a few years ago, are dramatic examples of the process. As the higher-grade deposits become worked out, the need and economic opportunity for successfully working with low-grade ores are increased.

As the principal owner of the undeveloped mineral domain, as a major buyer and user of mineral products, as the guardian of the national security, and as the principal regulator of economic policy in the mineral field, the Federal Government has a preeminent interest in better utilization of low-grade mineral resources. Here, too, the Federal Government should sponsor research designed to catalyze private study of mineral deposits.

In its report, the President's Materials Policy Commission pointed out that development of effective means of highway transportation, coordinated with land and resources use planning, is essential to the utilization of resources. Highway planning is also connected with urban development and housing in that there should be coordination of plans for moving people into, within, and out of city centers. Moreover, highway construction that is compatible with master metropolitan planning can be used to clear slum areas. The Federal Government is actively interested in redevelopment of urban centers, in housing, and in its \$50 billion Federal highway program. Research to guide planning and decisionmaking in these interconnected topics is a vital national need.

#### *International relations*

Any consideration of Federal expenditure policy for economic growth and stability must respect the impact of the outside world. The strength of our economy not only influences the condition of other nations and our relations with them but has a material effect on a significant portion of our own economy. With the stakes in international relations so high in terms of national survival and with ever-changing conditions, our relations with other countries require a greater degree of creative study than ever before.

Although research on problems of international affairs is now a major occupation in government and elsewhere, Federal expenditures in this crucial field are minute in comparison with those on military research and development. For example, the Department of State spent about \$351,000 on research in fiscal 1957. It is time to ask whether a much more intensive effort on behalf of peace through research on political, social, and economic measures to reduce international tension is not now in order.

No less an expert than the United States Ambassador to Egypt, Raymond A. Hare, stated recently :

I would venture to suggest to you that no small amount of the grief and frustration encountered in both the framing and understanding of foreign policy could be avoided if foreign policy were approached more as a science and less as a politi-

cal rough-and-tumble with esoteric overtones. For, as a result of some reading on foreign affairs and some slight personal experience in that field, I have been increasingly impressed by the recurrence, in greatly changing circumstances, of identifiable phenomena which lend themselves to analysis, classification, and the drawing of basic and subsidiary conclusions. Whether these conclusions can yet be classed as laws in the scientific sense is debatable and it is not my purpose to press that particular point to conclusion with you today. There is no question in my mind, however, that such deductions do prove that the study of foreign policy can be pursued beyond mere action and reaction and also beyond the evoking of historical precedents, immensely valuable as that may be.

How, then, can research aid the official who makes decisions in international affairs? As a general guide, foreign policy should be anticipatory rather than reactive, wherever possible. This implies the possession of adequate facts and analyses in advance of probable events, at the least, and of some important possible events in addition. From this information consistent policies should be distilled in advance of emergencies, and courses of action formulated in event of need.

In the light of tensions between our country and the Soviet Union we know that it is prudent to spend large sums for research on new weapons systems. This same motivation suggests that it might also be wise to conduct more research on means of changing the spirit and attitudes of Soviet leaders. This would be part of finding a really feasible way of dealing with the Soviet bloc without the continuous succession of crises and palliatives.

As we succeed in finding means of easing tension we need to undertake research that can guide negotiations for limitations of armaments. Political, military, technical, psychological, and economic factors are intricately interwoven in this problem. The interdisciplinary team approach of applied research may succeed in penetrating this barrier and hence ease international tensions. It is difficult but nonetheless essential for our representatives in arms-limitation discussions to assess the implications of arms-limiting proposals. These proposals may be symmetrical or asymmetrical, but before they are advanced or accepted by us the clearest understanding possible of their probable consequences is necessary. Even if the likelihood of a research breakthrough in this area is slim, the risks of not understanding are so great that research should be given a chance to illuminate this problem area.

Should international tensions lessen, our policymakers need to be better prepared with facts and analyses than they are today to deal with the adjustments that would be required. It is likely that national-defense expenditures could be cut drastically in such a contingency. We need research to discover all the major impacts of such a situation and to devise means by which the transition can be accomplished without undue hardship to any sector of our people.

Another potential change to which our economic system may be called upon to respond is the possible widespread reduction in tariff barriers among many countries. Europe's common market is just getting into operation, resulting in regional adjustments in import duties that will modify the character of economic enterprises there and in other countries with whom European firms trade. It is con-

ceivable that an effective means of achieving the foreign-policy objectives of our country may require sharp reduction in parts of our own tariff structure. At present our knowledge of economic dynamics allows us neither to anticipate with any certainty the consequences of changes nor to establish the corrective measures that would make for a successful transition. Research can illuminate this contingency.

In spending vast sums on foreign economic aid, the United States has been rewarded with both successes and disappointments. Some of the disappointments are attributable to failure to establish criteria of economic development for each country where an attempt is made to create something which has never before existed. Better results could be obtained by a more searching analysis and comparison of patterns of economic and social development.

Not only are the resources of the United States finite, but any program of foreign aid will operate, like all other governmental activities, within the budget limitations imposed by domestic political and economic considerations. Research is needed here, too, to establish priorities among foreign-aid goals and to determine the effects that different levels of American foreign aid might produce.

Fully recognizing that foreign aid and economic development are complicated by the broader aspects of political relations among nations, we nevertheless believe that relatively small increases in expenditures on research will yield an appreciably greater payoff in the success of the foreign-aid program and in its benefits to the United States than most other comparable expenditures of funds.

### *Summary*

Some say that work today is progressing satisfactorily on most of these important problems and that solutions will appear in the course of time. We agree with such a viewpoint, but we also contend in the strongest terms that progress is so slow as to make it unlikely that the solutions will emerge before the most serious damage has been done to our society and our economy.

Others say that research on these important topics is not a function of the Federal Government and would be too expensive. To these we reply that if the Federal Government does not take the initiative, no action is likely, and that the cost would be so small relative to the cost of not solving the problems that the comparison is not even relevant.

What is proposed is research that will come up with feasible answers to questions of vital public, social, and national concern. Each answer would have a number of alternatives with respect to procedures and approaches. What answers are considered best, what alternative procedures are deemed most favorable—indeed whether any action should be taken at all—is, of course, a matter for the Congress and the American people.

### RESEARCH COORDINATION

In view of the large and increasing volume of research now being undertaken by and for the Federal Government, and the large and increasing volume being undertaken by private business and other agencies, the need is evident for coordination in these efforts. This need will grow more rapidly than research volume grows, because

the pattern of interdependent and overlapping investigations will become more complex.

Because the capabilities of research are most widely recognized in the Department of Defense, research coordination is more advanced in that Department than in other parts of the executive branch.

There, an Assistant Secretary of Defense for Research and Engineering performs valuable coordinative functions on a staff basis for all the military services. The effectiveness of this office is being further enhanced by the creation of positions of Assistant Secretary for Research, or Directors of Research, in each of the three services. This pattern of research coordination is in keeping with the best practices in corporate research management. Most research-minded companies do have a vice president of research who has advisory and coordination powers over several decentralized research groups in the corporation.

It is our recommendation that a sound immediate step for achieving better research coordination and for stimulating the research approach in nondefense activities would be to extend this aspect of the Defense Department's organizational structure to the other executive departments. In short, there should be created Assistant Secretaries for Research in the Departments of Agriculture; State; Commerce; Interior; Health, Education, and Welfare; Justice; Post Office; Labor; and Treasury. These officers would give appropriate stature to research in each Department. Together they would form a group through whom interdepartmental research coordination could begin, just as interservice coordination is now occurring within the Department of Defense.

At the present time, some of the functions of overall coordination and evaluation of the Government's research programs are assigned to the National Science Foundation, the National Research Council, Interdepartmental Committee on Scientific Research and Development, and the Bureau of the Budget. The Nation's total research effort could be more effective if, as a second step, one of these agencies were authorized to extend its coordinative role and to take an active as well as a passive approach in research matters that cut across departmental boundaries.

For neither the departmental nor the central research coordinating groups does this paper advocate setting up a whole new agency. Neither do we suggest the creation of entirely new powers of control in any group. We do urge strongly that the Congress encourage the executive branch to organize itself to do what will be described in succeeding paragraphs, and then make sure that necessary funds are provided, that qualified specialists are employed, and that they get about the job.

Before describing the central, interdepartmental coordinating functions that are needed, this paper can possibly put to rest some misapprehensions that arise inevitably when this subject is brought up for consideration. It is not proposed that any agency, board, commission, or committee be established to decide what research shall and what research shall not be undertaken by the Federal Government. It is not proposed that the central body do any research of its own, except a special kind of research on research that will be outlined at a later point. It is not proposed that every new Federal

research project necessarily be submitted to this body for review before adoption. It is not proposed that this body delve into every detail of every Federal research program.

What is proposed is a body that will provide a management-aid service to the Congress and to the executive department as a whole to help them in making decisions on authorizations, appropriations, and programs. In addition, it is proposed that this same body be a representative of the Federal Government in contact with research activities outside the Government to bring about more effective cooperation in the whole research community. In this latter respect it would supplement, not supplant, the contacts now in existence at many levels of research. Finally, it is proposed that this agency constantly seek to stimulate and catalyze private organizations to sponsor and perform research that is inspired by or derived from the initiative of federally sponsored research.

The first task of such a body would be to make an inventory of Federal research programs, their objectives, their plans of approach, their staffing, and their schedules. This would be a perpetual inventory kept just as current as it may turn out to be feasible to maintain, but certainly brought up to date more frequently than once a year.

The second task of such a body would be to examine the inventory to determine what duplications and inconsistencies may exist, so that a full report can be made periodically to affected agencies on the nature and extent of these aspects. It is not suggested that all duplications and inconsistencies be eliminated, for progress in research can often be accomplished expeditiously only by exploration of several approaches simultaneously. We nevertheless think it important that all persons involved know what is going on, so that no more of this kind of thing exist than is consistent with a vigorous and comprehensive attack on the problems which are being examined. The reports should contain comments on those features which are considered to be clearly of questionable value in this sense.

The third task of such a body, and the most important, would be a function that will be called evaluation—for want of a fully descriptive term. It is here that research on research comes into the picture. What is required is an examination of each research program to discover how well its plan of attack matches the objectives set forth for it and, more basically, to discover how well its objectives fit into the dynamic nature of the economy and society it is expected to affect. This examination in turn is dependent upon a well-worked-out concept of what the set of programs as a whole is expected to accomplish for the Nation.

From the foregoing evaluation it should be possible for the coordinating agency to make the following kinds of contribution to the effectiveness of Federal research efforts: (1) advise higher levels of effort for programs that are below the required threshold or moving too slowly to meet projected needs of a dynamic technology and economy; (2) recommend removal of support for projects involving unnecessary duplication or for which changing conditions will eliminate the need; (3) identify gaps that justify new projects; (4) interconnect projects that can benefit from interaction of methodology or observations.

Some progress in research evaluation of this type is being made in connection with certain military research programs. It has been

found that the unifying principle in many cases is time. In any consideration of our military offensive and defensive posture and the weapons systems, strategy and tactics required, we must look at these matters in a time frame. It may be of little importance to us to develop a manned atomic bomber of indefinite cruising range if, by the time we can expect to have such an aircraft operational, it would be likely that a potential enemy would have defense weapons easily capable of knocking such a bomber out of the air a long way from its target. If we look at our probable offensive and defensive posture in the future as a moving picture—actually as in the case of the moving picture a series of stills at intervals of time—we will be able to see more clearly where efforts are being made that can't possibly be of much help, when gaps are likely to show up that are not now being worked upon, and, in general, how best to match the research conducted to the military requirements.

Needless to say, the nonmilitary problems are not necessarily the same as the military. The time-frame idea may not be appropriate in some cases. But many of these nonmilitary problems do have a time reference; for example, the waves of persons expecting to enter the labor force in the future or the exhaustion of supplies of fossil fuels. Others cannot be pinned down so precisely, but are still in some way time phased, so that part of the degree of urgency can be established by reference to the period of time which will elapse before the problem becomes serious and by reference to the period of time (called lead time in military parlance) in which it might be expected that a solution could possibly be achieved and implemented.

Another fairly significant task for the research coordinating body would be the making and maintaining of an inventory of research efforts outside the Federal Government which bear upon problems of national interest. This inventory would be useful not only as information available to all research workers, but it would lead to efforts by the Federal Government and by the outside organizations to bring about cooperation in some fields of mutual concern. There is a place for an organization within government which could encourage cooperative research activities among governmental agencies, the private foundations, and private industry.

The research coordinating body described in this paper would have no direct power to control research. It can be effective only to the extent that its findings and recommendations are so well worked out and supported by evidence that its work received recognition in the deliberations of the Congress and the executive departments. Fundamentally, the outcome of its efforts will depend on the prestige it generates by the quality and independence of its work.

But good work would depend rather significantly at the outset upon the standing and support it is given. Not much good can be accomplished by assigning duties and providing a small budget and then throwing the group onto its own. If it is concluded that the objectives outlined here are desirable, then the sponsor, the Federal Government, would have to do what is required in all effective research programs—have the confidence to back the efforts strongly from the beginning both with funds and recognition.

Such action would have its risks, as in all research; not every investigation would pay out. But the need is so very great that, in the

view of this paper, it must come eventually if not immediately. If delayed, there will be corresponding loss to the welfare of the country.

In this connection, there is every reason to believe that the coordinating body would save its cost and, indeed, lead to research results or current programs at less expense than now contemplated. At the same time, we do not take the position that research expenditures after the establishment of the coordinating group would be likely to be lower than at present. The work of the group would inevitably bring to light fields in which more research would bring about advances of very great worth to the operating of the Federal Government and to the public at large.

Through the creation of Assistant Secretaries for Research in each of the nondefense departments and through interdepartmental research coordination as described above, an acceleration of research on pressing public problems would be bound to occur. This would help to correct the serious disparity between social and technical progress, bringing the former's straight-line progression more nearly into conformity with the geometrical rate of technical advance.

#### APPENDIX I. TRENDS IN FEDERAL RESEARCH AND DEVELOPMENT OBLIGATIONS

For an appreciation of the increase of research and development activity supported by Federal funds, it is necessary to look at obligations for the conduct of current work and for the provision of additional research and development plant, without consideration of the pay and allowances of military personnel or certain expenditures financed through military procurement contracts. The latter two items are included in the current rate of expenditure for research and development of \$3 billion, but no estimates are available for them except for the last few years. The obligations for which data are available more than tripled in the years since 1947, growing from \$793 million in that year to an estimated \$2,880 million in fiscal 1957, as shown in table I. Even if account is taken of probable underreporting in earlier years and of the decline in the purchasing power of the dollar, obligations in real terms have in all likelihood more than doubled.

Most of the statistical information given here is based on data from the annual issues of Federal Funds for Science compiled by the National Science Foundation and from the annual Federal budgets. These data, however, have been supplemented by estimates of unreported data, have been reworked, and have been presented in different ways to highlight some of the issues which are emphasized in this paper. No attempt is made to separate applied from basic research in these analyses, as the latter is relatively small in amount.

While the source figures are indicative of the general position of Federal research and development and some of its aspects, it must be admitted that the accuracy is something less than might be desired. As the Foundation remarks in its reports, the data were obtained from the agencies concerned and in many cases were estimates based on judgment determinations of what should or should not be included. Many difficulties of definition exist, and accounts are not kept in such form that even approximations can be obtained without considerable effort. If the view taken by this paper is correct—that much of the

effectiveness of decisions relating to the selection of equipment, methods, and policies depends upon the adequacy of the research that precedes such decisions—it would appear that even more effort should be made to find out what research is going on. The difficulties, and indeed they are formidable, should not be allowed to deter the making of a major effort. It is conceivable that what is needed is not more funds but a better allocation of the amount currently being expended.

The following set of comparisons deals with defense research (termed “national security” research and development by the Bureau of the Budget). The data refer to obligations by fiscal years for the conduct of current work and for increase in plant. Military pay and activities financed by procurement contracts are not included.

Table I shows Federal research and development obligations for each year from 1947 through 1957. Table II shows obligations for research and development related to national security and compares them with national defense expenditures for goods and services. Information on nondefense agencies is summarized in table III. Table IV provides data on Federal and private nondefense research expenditures and compares them with the value of the activities they support.

TABLE I.—*Federal research and development obligations,<sup>1</sup> fiscal years*

[In millions of dollars]

Year	Conduct of work	Plant	Total	Total in 1947 dollars
1947.....	722	71	793	793
1948.....	781	91	877	873
1949.....	954	167	1,121	1,092
1950.....	1,041	203	1,244	1,170
1951.....	1,521	330	1,851	1,625
1952.....	1,909	307	2,216	1,854
1953.....	1,919	248	2,167	1,845
1954.....	1,762	156	1,918	1,629
1955.....	1,927	207	2,134	1,757
1956.....	2,231	350	2,581	2,124
1957.....	2,520	360	2,880	2,210

<sup>1</sup> Included in these figures are the amounts obligated for general-purpose statistics which have been excluded by the National Science Foundation in its last 2 reports. They have been restored for purposes of this paper because (1) they provide important data for the making of management decisions both by Government and industry; (2) they have at least as much research content as many of the programs still included; and (3) while there is some variation from year to year, other programs still included vary much more. The National Science Foundation appears to have included no obligations for the Manhattan Engineer District in 1947. This was the transition period to the Atomic Energy Commission. No doubt this treatment is strictly accurate from the point of view of obligations, but it makes the AEC figure in 1947 appear very small. Half the reported expenditures for MED are added to AEC obligations. Deflation is by the implicit deflator for Federal Government purchases of goods and services as published by the National Income Division, Office of Business Economics, Department of Commerce.

TABLE II.—National security (defense) obligations for research and development, fiscal years

[In billions of dollars]

Year	Conduct of work	Plant <sup>1</sup>	Combined plant and conduct	Combined in 1947 dollars	National security purchases	Ratio, research and development to national security purchases
1947.....	0.629	0.083	0.712	0.712	13.3	5.4
1948.....	.662	.081	.743	.740	13.7	5.4
1949.....	.802	.080	.882	.859	18.4	4.8
1950.....	.813	.088	.901	.847	17.9	5.0
1951.....	1.327	.098	1.425	1.250	25.7	5.5
1952.....	1.726	.127	1.853	1.550	45.2	4.1
1953.....	1.730	.152	1.882	1.601	51.5	3.7
1954.....	1.560	.171	1.731	1.471	47.6	3.6
1955.....	1.668	.179	1.847	1.520	41.3	4.5
1956.....	1.930	.196	2.126	1.679	41.2	5.2
1957.....	2.125	.233	2.358	1.806	44.7	5.3

<sup>1</sup> Obligations to increase plant have been amortized over a period of years. The adjustment was very rough because little is known of the appropriate depreciation rate and, in any event, only a few years' data are available. The plant obligations were spread on a straight-line basis over the 8 years following the year of obligation. Nothing was known of the accumulation in 1947 and it was assumed that, at that time, plant bore the same relationship to obligations for conduct of work as in 1955. The figure so obtained was reduced by  $\frac{1}{8}$  in 1948,  $\frac{3}{8}$  in 1949, etc., until elimination in 1955. The real objective of this process was to spread the plant obligations so they would not be bunched, and the only justification of the process is that it gave what appeared to be reasonable results.

TABLE III.—Federal obligations for research and development agencies other than national security agencies, fiscal years

[In millions of dollars]

Year	Conduct of work <sup>1</sup>	Plant <sup>2</sup>	Combined plant and conduct	Combined in 1947 dollars
1947.....	104.6	7.6	112.2	112.2
1948.....	134.3	7.9	142.2	141.7
1949.....	156.0	8.5	164.5	162.0
1950.....	184.8	10.4	195.2	183.6
1951.....	179.2	13.8	193.0	169.3
1952.....	185.9	15.1	201.0	168.1
1953.....	197.0	16.4	213.4	181.6
1954.....	213.0	17.5	230.5	195.8
1955.....	249.6	18.2	267.8	220.2
1956.....	304.9	17.7	322.6	244.7
1957.....	350.0	17.8	367.8	281.3

<sup>1</sup> Obligations for periodic census programs do not show any time trend and have been evened out over the years by attributing to each year the average for the years 1945 to 1957.

<sup>2</sup> Amortized by the same process employed for national security research plant.

TABLE IV.—*Federal and private business expenditures for nonsecurity research compared with selected Federal and private production activities, fiscal years*

[In millions of dollars]

Year	Federal research	Private business research	Total	Product <sup>1</sup>	Ratio, re- search and develop- ment to product (percent)
1947.....	90	1,410	1,500	112,200	1.34
1948.....	120	1,650	1,770	132,300	1.34
1949.....	140	1,620	1,760	139,100	1.26
1950.....	160	1,640	1,800	143,900	1.25
1951.....	170	1,870	2,040	161,900	1.26
1952.....	180	2,050	2,230	177,200	1.26
1953.....	190	2,220	2,410	187,500	1.28
1954.....	190	2,450	2,640	189,100	1.39
1955.....	220	2,800	3,020	192,500	1.57
1956.....	270	3,230	3,500	207,500	1.69

<sup>1</sup> Gross product in agriculture, mining, manufacturing, transportation, communications, public utilities, and medical health plus Federal nondefense purchases of goods and services.