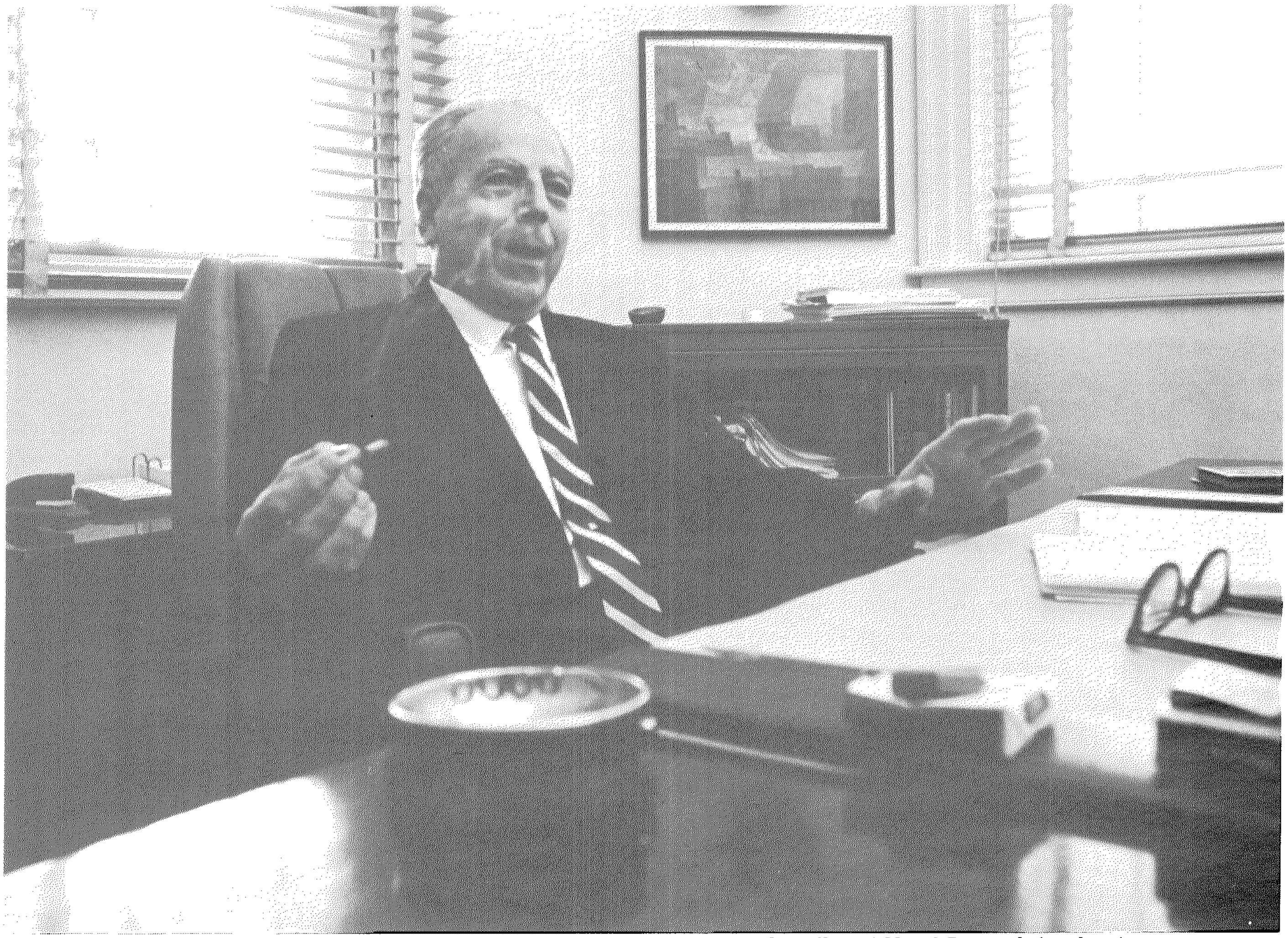

Arthur Laufer, deputy director and chief scientist of the Office of Naval Research for the nine western states.

"From World War II through 1957, federal support was sustained by faith in science; from the time of Sputnik in 1957 into the 1960's, it was sustained by the fear of Soviet competition. These have now been exhausted as justifications . . ."

The Sponsorship of Basic Research

by Arthur Laufer

The search for new technology is often best approached by indirection.

The late Charles F. Kettering, vice president of General Motors and inventor of the automobile self-starter, defined basic research ungrammatically as "something that if you don't do it until you have to, it's too late." Some academicians call it "pure" science, thereby making a value judgment; and some cynics call it "useless" science —another value judgment. The National Science Foundation defines basic research as "the search for an understanding of the laws of nature without regard to the ultimate application of the results." The Department of Defense defines it as "that type of research which is directed toward an increase of knowledge in science. In such research, the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than any practical application thereof." A typical industrial definition is "original investigations for the advancement of scientific knowledge that do not have specific commercial objectives."

Presumably, research which is not "basic" is "applied," or directed toward a practical application. In point of fact, whether a given research project is basic or applied is in the eye of the beholder. It often may be either, depending on the motives of those conducting the work and those sponsoring the work, and, furthermore, it may be basic for one and applied for the other. For example, a university scientist received Navy support for what in his eyes was a "basic" research project in biology entitled "Sweat Glands of the Australian Aborigines." A U. S. senator questioned why such work should be supported by the Navy. He was satisfied when he was informed that the aborigines perspire very little, and that if we could learn why, the knowledge might help us in our undersea programs where men have to live in confined spaces, and water vapor removal is a substantial problem.

Whether a research project is termed basic or applied is primarily a matter of semantics and viewpoint. However, in the hierarchy of science, basic research is claimed to stand higher than applied research. This attitude is unfortunate both because there is much excitement and intellectual satisfaction in good applied science, and because science has always ultimately been justified by its contributions to the welfare of mankind.

But, be it viewed as basic or applied, most of the research done in universities is funded by the federal government. The mutual dependence of the government and the universities in basic research is one of the most significant developments of our time. Last year about $26 billion was spent on research and development in this country; about $17 billion of that came from the federal government. The amount devoted to basic research in universities is impressive: Last year the government provided about $1.4 billion for university research.

This overwhelming involvement of the federal government in academic science is clearly a modern phenomenon. Before World War II the federal government supported some science, but, outside of agriculture and some geology, very little in the universities. In those days, funds for university research came from a number of highly selective philanthropic foundations and from the meager operating funds of the schools themselves.

When war came to Europe, the question arose as to whether science in this country could be mobilized in our own defense. Most of the nation's best scientists at that time were on university faculties, a situation different from that in most European nations. It was therefore necessary to try to develop a mechanism for using the scientific talent in the universities, even though no tradition of substantial government support of university research had previously been established.

In 1940 President Roosevelt established the National Defense Research Committee (NDRC) to "conduct research for the creation and improvement of instruments, methods, and materials of warfare." A year later it was superseded by the Office of Scientific Research and Development (OSRD), headed by Vannevar Bush, which provided support for university scientists doing research judged important to the national security. Where large concentrations of scientists were needed for large problems, organizations were created—such as the Radiation Laboratory at MIT, headed by Lee DuBridge, where very successful work on radar was done.

Most of this research was, of course, applied research and war-related. A large number of university scientists were involved, great technical advances were made, and the results of organizing the scientific potential of the nation were dramatic. However, OSRD was a temporary wartime organization and went out of existence automatically at the end of the war in 1945.

Even before the end of the war, many influential people felt that it would be unwise to allow science, after the

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war, to slip back to the level of prewar scientific activity, These general feelings were given coherent expression in 1945 in the report of a special presidential committee of distinguished scientists, educators, and industrialists, headed by Vannevar Bush. This report, entitled *Science—The Endless Frontier,* provided a blueprint and a timetable for the postwar expansion of the federal support of science.

The committee proposed creation of a National Research Foundation to support basic research, on a large and increasing scale, primarily at universities. But it was not until 1950, five years after the end of the war and the end of OSRD, that a bill was finally passed and signed by President Truman, establishing the National Science Foundation. Its initial appropriation was only $225,000 for 1951, a far cry from the high hopes expressed during the war. This funding was not nearly enough to prevent science from slipping back into the prewar "sealing wax and string" days. Not until 1957, following Sputnik, was the NSF budget raised to the level proposed back in 1945.

However, the United States Navy was standing in the wings, ready, willing, and able. For many generations the Navy had had a strong interest in science, and during the war a group of young, scientifically trained Naval officers began worrying about what would happen to research when OSRD went out of existence. With the support of a number of eminent scientists, they persuaded the Navy in 1945 to establish the Office of Research and Inventions, which merged several Navy research organizations into a single agency.

At this time, with Congress embroiled in the bitter arguments concerning the establishment of the National Science Foundation, it was apparent that a civilian research-supporting agency would not be established by the time it was needed. The Navy, determined not to allow OSRD's research momentum to be dissipated, arranged for the submission of a bill to Congress for the establishment of an Office of Naval Research, which was to absorb the Office of Research and Inventions. Congress established the Office of Naval Research in 1946 and gave it authority for conducting a broad program of scientific research under contracts with civilian organizations.

Thus, the Navy found itself the sole government agency with the power to move into the void created by the phasing out of the OSRD. Ironically, although the civilian OSRD had been concerned primarily with applied, war-related, classified research, the military ONR was to be concerned for many years primarily with basic, non-war-related, unclassified academic research.

As the first permanent federal agency charged with the primary mission of supporting basic research in universities, ONR had to develop a new type of contract which would be acceptable to the universities and would still protect the government interest. Some universities were fearful that federal support would mean federal control and that onerous restrictions would be imposed. ONR developed a system that invited the submission of unsolicited proposals, in lieu of the time-honored system of competitive bidding. The principal product of the contract was acknowledged to be a report or preferably a paper in a scientific journal, rather than hardware. The contract was to be monitored with official restraint and a minimum of reporting.

These features, which seem natural now, were revolutionary in 1946. This display of understanding of the nature of research and of the latitude necessary in the contractual relationship won over the scientific community, and ONR was deluged by a flood of proposals.

By 1949 ONR had 1,200 contracts in 200 institutions, engaging the efforts of 3,000 scientists and 2,500 graduate students. The provision for the support of graduate students as research assistants to the principal investigators was a significant innovation. When the AEC and the NIH began contracting for research, and when the NSF and later the Air Force Office of Scientific Research, the Army Research Office, and NASA were established and undertook their research-supporting efforts, the ONR policies served as their model.

Over the years ONR has sponsored a broad spectrum of scientific research in all the sciences. Much significant work has been supported at Caltech, including Carl Anderson's work in cosmic rays, the Lauritsen-Fowler work on low-energy nuclear physics and nuclear astrophysics, the Owens Valley Radio Observatory, and even much of Linus Pauling's work on proteins.

Today, although the Office of Naval Research still has a budget of over $160 million and more than 2,000 contracts, it supports only a small fraction of the ongoing research in the country. Also, even though many ONR-supported investigators believe their research to be "basic" in the sense discussed earlier, ONR now restricts its support to projects which it views as clearly relevant to its mission. Nevertheless, the results of its early influence are still being felt.

On the occasion of the dedication of the Owens Valley

Radio Observatory in 1961, Lee DuBridge said: "To ONR, the scientific world owes an enormous debt of gratitude for pioneering the way in which the government could assist the universities in the prosecution of the search for basic knowledge and the training of graduate students in scientific and engineering pursuits, and these techniques have been widely copied in other agencies of the government today."

In the year 1966, ONR's twentieth anniversary, Professor Harvey Brooks of Harvard said: "As one reviews the history of American science and technology in the last 20 years, one cannot fail but be struck by the strategic role which ONR-sponsored work has played. In fact, when one considers its present minor fiscal role in research support compared with what it was in the early days, one is surprised at its still major importance and influence. Wherever the most important advances are being made, one still seems to find ONR present with at least some support. A catalog of areas in which ONR-sponsored scientists have pioneered shows how frequently ONR has been there with the right science at the right time, even though few foresaw the usefulness and relevance when ONR first began to sponsor it."

These statements are quoted here in order to make a point: that the existence of a number of different mission-oriented research-sponsoring agencies, of which ONR is only one, each with its own motivation, is good for science.

Still, the existence now of so many similar research-sponsoring agencies leads, from time to time, to serious proposals that basic research ought to be supported through one super agency, in part to achieve administrative neatness.

Such a system would be fraught with danger.

The various mission-oriented agencies of the government have urgent need for the scientific talent of the universities to assist in the solution of our many national problems, ranging from the conquest of disease to the provision of an adequate national defense. A single monolithic agency cannot be relied upon to have the wisdom needed to support in sufficient depth the various areas which are of overriding importance to the missions of the other agencies.

The diversity of our present system for the support of academic research is probably the greatest source of our scientific and technical strength. There is no single best way to support science. Our scientific choices are now governed by a wide range of priorities, environments, and motivations, leading to a strong and flexible system. The fears of federal control coming with federal funds have proved unfounded perhaps largely because the funds have been injected through a variety of agencies for a variety of purposes. The multiplicity of alternative sources of support is, I believe, one of the most important safeguards for the independence of the individual scientist.

A monolithic science-support agency would be highly vulnerable to Congressional action. From World War II through 1957, federal support of science was sustained by faith in science; from the time of Sputnik in 1957 into the 1960's, it was sustained by the fear of Soviet competition. These have now been exhausted as justifications, and the Congress demands that the present emphasis be on utility. The Congress recently has revealed an apparent loss of confidence in the worth of basic research. The mission-oriented agencies can often provide justifications for the support of science which are more readily endorsed by our legislators than are the justifications for "pure" science.

Consider another aspect of this problem. Every agency must plan its research program to match the available funds and to attempt to place its support in areas which are likely to prove productive. Such planning must inevitably be based on predictions of the future, and, unfortunately, our crystal balls are very cloudy. This difficulty would be compounded many times over if all the planning of science support were in the hands of a single agency. Let me give a few examples of our lack of foresight.

A technical forecast in 1937 missed computers, atomic energy, antibiotics, radar, and jet propulsion. Yet all of these were incorporated in successful systems within a few years after the forecast.

Another example. Vannevar Bush, in testimony before the Special Senate Committee on Atomic Energy in December 1945, said: "There has been a great deal said about a 3000-mile high-angle rocket. In my opinion such a thing is impossible . . . The people who have been writing these things that annoy me have been talking about a . . . rocket shot from one continent to another carrying an atomic bomb, and so directed as to be a precise weapon which would land on a certain target such as this city. I say technically I don't think anybody in the world knows how to do such a thing and I feel confident it will not be done for a very long period of time to come. I think we can leave that out of our thinking." On the same subject, Frank Malina said last year that in 1936 Clark Millikan was dubious about the future of rocket

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propulsion, and that in 1938 a senior Army officer on a visit to Caltech stated there was little possibility of using rockets for military purposes.

In the 1930's Robert Millikan, in answer to an English bishop's proposal that a 10-year moratorium be imposed on research to allow civilization time to cope with its creations, said: "The bishop need not worry about science, or about the absurd possibility that mankind, armed with the energy of the atom, might blow itself to kingdom come. That energy is destined to stay locked in the atom. The Creator has put some foolproof elements into his handiwork and . . . man is powerless to do it any titanic damage." Similarly, in 1933, Lord Rutherford, the father of nuclear physics, said: "Anyone who expects a source of power from the transformation of the atoms is talking moonshine." Karl Darrow published a paper presenting five reasons why Nature would never allow a chain reaction to take place. In 1938 nuclear fission was discovered by Hahn and Strassman, and in 1942 a chain reaction was achieved by Fermi.

In 1944, Theodore von Karman said: "Obviously, it is an intriguing question whether there are any intrinsic limits for flight velocity. Many people will ask 'Shall we ever fly faster than sound?' I do not believe that at the present this question can be answered by a straight yes or no." In the same lecture he said: "To some extent the question of supersonic flight is analogous to another intriguing problem discussed sometimes by serious men, more often by authors having more imagination than scientific knowledge. I mean the question of the feasibility of navigation off from the gravitational field of the earth. Of course, some fabulous new fuel would change the situation completely in both cases. However, basing the consideration on power plants and fuels which are available or which we hope to have with reasonable expectation, the answer to the question of the feasibility of planetary navigation is probably negative." This talk was given in April 1944; on October 17, 1947, Captain Charles Yeager of the Army Air Force flew the Bell X-1 rocket research aircraft at supersonic speed in level flight.

One should also not forget that in the 1890's a Bishop Wright said that God did not mean for us to fly—if He had, He would have given us wings. Bishop Wright had two sons, named Wilbur and Orville.

Now, I have not presented these examples to deride a number of eminent and extremely competent scientists of the past. I am merely seeking to show that none of us, not even the best of us, is very competent in predicting the future. And this is why planning fails and cannot help but fail.

The search for new technology is often best approached by indirection, and a decentralized pluralistic decision-making system such as we now have, with a multiplicity of research-sponsoring and -planning agencies, provides us with a redundancy which serves to minimize the harmful effects of high-level planning.

Finally, I would like to make some reference to the attempt by some segments of the academic community to force the termination of all defense-related research on university campuses. I have great sympathy for those who would like to see science more deeply involved in socially constructive activities, who are concerned about the uses to which science is being put, and who have a hunger to make science relevant and benign. However, the elimination of defense-related research from the campus would not solve the problems they wish to see solved, and would introduce certain new problems.

First, most of the research supported by the DoD on university campuses, though highly relevant to DoD needs, is regarded by the investigators as basic research. But not only the DoD benefits from this research; the so-called socially constructive agencies benefit at least as much. For example, the Navy pioneered and developed techniques for preserving whole blood for relatively long periods of time by means of rapid freezing techniques. While it is true that such preserved blood is of great medical value for military personnel aboard ship, many more civilians will benefit from the resulting improvement in operation of blood banks throughout the country. On the other hand, there are many cases in which the results of NSF-supported research have been used by the military for less humanitarian purposes.

The fact is that the results of free and unhampered basic research, freely published, may be used by any agency of society for whatever purpose. A scientist seeking support for basic research from a particular agency does not necessarily share the motives of that agency. He has his own, presumably lofty, motives for undertaking that research. Similarly, if the research is truly basic, it would be difficult for him to assess the ultimate social consequences of his work, whoever the sponsor might be. It appears to me that it is the nature of the research which is important, not the identity of the sponsor. Hence, forcing DoD research off campus into research institutes and industrial laboratories will not prevent the DoD from benefiting from the non-DoD research which remains on campus, but will deprive the faculties and graduate students of hundreds of millions of dollars of research support which is sorely needed for both scientific and educational purposes.

Second, if DoD research were forced off campus, there is no assurance that the scientists on campus would be able to turn their efforts to "social" problems. Social desirability does not insure technical feasibility. The reason why many scientists apply for DoD support is that the basic science problems which the DoD will support are comparatively easy problems which discipline-oriented scientists know how to attack. The difficult social problems of racial intolerance, urban congestion and decay, pollution of the environment, and international tension and conflict—depending as they do on the preferences, desires, and emotions of human beings—do not yet appear to be amenable to solution by the techniques which scientists know how to employ.

Finally, it is clear that American society places a high value on military strength for defense. Most Americans believe that our country cannot rely for survival upon purely ethical superiority in a world which includes the Soviets and Czechoslovakia, the Biafrans and the Nigerians, Israel and the Arab countries, and mainland China. The USSR is increasing its military R&D effort at a disturbing rate, and both West Germany and Japan have announced plans for major increases in their efforts. Even the disenchantment with the Vietnam war has not made America feel that defense is dishonorable and unethical. Of all the unforgivable things the Department of Defense might do, in the view of most Americans, the most unforgivable would be to allow this nation to be conquered through a technological surprise. They have not forgotten what the world now would be like if Hitler's Germany had been the first to create the atomic bomb. Thus defense research is now and will long be, I am convinced, an integral part of our society. It is therefore difficult to understand how those who want the university to become *involved* in the problems of society now can demand that the university eliminate its involvement in the most serious problem of our society. They should demand, rather, that the university use all its considerable influence to assure that our military strength be used *only* for defense.

Disengagement of the university from defense research would deprive society of an important safeguard. The record shows that university scientists have consistently led efforts to awaken our society to the dangers of the misuse of technology, of the arms race, and of the pollution of our environment. Increasingly, major national decisions must be made on issues that involve considerable scientific or technological complexity, and therefore government agencies and their industrial contractors often have a near-monopoly on the relevant information. Participation of university scientists in DoD-related work gives them the technical backup they need to provide sophisticated and independent criticism of public policy. Defense research will be done, whether it is done on or off the campus. But if the university were to withdraw from DoD-related work and remain aloof, who else would be available to make independent analyses and challenge the government positions on complex technological questions?

The university serves a unique public-service function in defense research. It is to be hoped that the university community will avoid the practice of what Reinhold Niebuhr called "the strategy of fleeing from difficult problems by taking refuge in impossible solutions."