Federal Support of Science Technology

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Federal Support of Science and Technology

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PAST AND PRESENT

Introduction: Some History

Governmental support of scientific research goes back at least as far as the time of Alexander the Great, who, at the instigation of his former tutor Aristotle, took scientists along on his expeditions to the east for the purpose of collecting data and specimens on local flora and fauna. In more recent times governmental support of science has been symbolized by the granting of royal charters to groups such as the Royal Society of London. Perusal of the early volumes of the Royal Society shows a strong interest in practical applications of knowledge. It appears that applications, either present or potential, has always been a strong motivating force in the support of science. During periods when breakthroughs in scientific knowledge has led to important applications the vision of future benefits has been easier to behold. Thus Joseph Glanvill, a Fellow of the Royal Society, noted, in 1665, the benefits that science could bring (quoted in Disraeli, 1814):

> "Should these heroes go on (the Royal Society) as they have happily begun, they will fill the world with wonders; and posterity will find many things that are now but rumours, verified into practical realities. It may be, some ages hence, a voyage to the southern unknown tracts, yea, possibly the Moon, will not be more strange than one to America. To them that come after us, it may be as ordinary to buy a pair of wings to fly into remotest regions, as now a pair of boots to ride a journey. And to confer at the distance of the Indies, by sympathetic

> conveyances, may be as usual to future times, as to us in a literary correspondence. The restoration of grey hairs to juvenility, and renewing the exhausted marrow, may at length be effected without a miracle; and the turning the now comparative desert world into a paradise, may not improbably be expected from late agriculture."*

The tangible benefits of science in World War II appears to have similarly fueled the hope of future miracles, a hope to some extent realized in thermonuclear weaponry, satellites and laser technology. Some hopes, such as that for fusion power, have been postponed again and again. In a climate of shrinking resources the value of present cost of science support seems more prominent than the potential of future benefit.

In the United States governmental support of science and technology has been present almost from the beginning of the Federal government. The support has almost always been for tangible, recognized needs of the community in areas where individual or private group resources have been insufficient. The gathering and processing of information needed for the setting of national policy has also been a motivating factor. As an example of information gathering we may cite the census of population, held for the first time in 1790. As the complexity of our society grew so did the complexity of the census, and information on

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*Isaac Disraeli, "Quarrels of Authors", 1814. There are many editions of this work. See the chapter on the Royal Society.

economic and social conditions was subsequently added to the data collected and processed.

The history of some government bureaus involved with science and technology is instructive both as to motivation and as to modes of operation. The Lighthouse Service* was initiated on August 7, 1789, by the ninth law passed by the first Congress. The motivation was the necessity for an essential aid to navigation for the important shipping industry. For many years supply, inspection and new construction was handled by contract under the supervision of the Treasury Department. New lights were built to satisfy immediate and pressing local needs, with no overall plan. The only technical innovation in many years was the governmental purchase of a patent for a lamp and papabolic reflector in 1812, an apparatus which had been in use in Europe for some time. In the 1820's and 1830's European improvements, such as the Fresnel lens, not in use here, led to complaints as to the efficiency of American lighthouses, as well as to the need for the authorized new stations. From 1837 to 1842 several Congressional investigations were carried out. These resulted primarily in deferring work on many lighthouses and in the employment of a professional engineer to investigate. In 1845 a

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*Facts on the Lighthouse Service are taken from George Weiss, "The Lighthouse Service", Baltimore: The John Hopkins Press, 1926.

Treasury report recommended the creation of a Lighthouse Board but Congress took no action on this until 1851 when a planning board was created. Finally in 1852 a Lighthouse Board was set to superintend a Federal Lighthouse service. Under this plan government engineers were responsible for plans, drawings, specifications and estimates as well as for the superintendence of construction, renovation and repair, while materials for construction and repair were to be obtained by public contracts. This division of responsibility is typical of many government operations, with planning, specification and monitoring being the responsibility of the government and the provision of materials and services coming from contractors. For situations which are essentially routine and for which all elements are known the division is relatively straightforward. Where insufficient information exists research or experiment must be done first. Beginning in the 1850's research and experiments on lighting, buoys, fog signals, and other improvements on navigational aids has been carried out by Federal personnel. A description of the Lighthouse Service in 1926 includes research and manufacture of navigational aids among its activities and notes: "Much of the special apparatus used by the Lighthouse Service has been perfected and manufactured by the Service itself". Research and development can here be seen as a necessary pre-requisite to the

planning and specification function which is part of the government's responsibility.

The territorial expansion of the United States led to a number of expeditions from 1804 (Lewis and Clark) on to survey the newly acquired territories.* By the early seventies four surveys were simultaneously in progress each of which had been specifically authorized by Congress. This situation was felt to be unsatisfactory and Congress requested the National Academy of Sciences to make a study with recommendations. The Academy's report, submitted in December, 1878, noted the requirement for "a thorough knowledge of its [the public domain] geological structure, natural resources, and products". To accomplish this they recommended the establishment of the U.S. Geological Survey, "to be charged with the study of the geological structure and economical resources of the public domain". Here we note the absence of information felt to be necessary for public policy decisions, in an area and with a scope beyond the resources of private individuals and groups. The survey was established by law on March 3, 1879. Its first Director, Clarence King, presented the case for a broad survey in his first annual report:

> The great extent of the United States and the widely separated sources of the national resources render the acquisition by private citizens of information on almost any single product always difficult, often impossible.

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*The facts regarding the Geological Survey are taken from the Institute for Government Research, "The U.S. Geological Survey", New York: D. Appleton, 1918.

> As a direct result of the size of the country, the government and people have long been uninformed as to our primary industries; those, I mean, which yield the raw materials - mineral, vegetable, and animal....
>
> Statesmen and economists, in whose hands rest the subjects of tariff and taxation, have no better sources of information than the guesses of newspapers and the scarcely less responsible estimates of officials who possess no adequate means of arriving at truth. (p.10)

The Congressional acts of 1879 and 1882 specified as functions the geological survey and classification of the public lands, and examination of geological structure and mineral resources and products, and the preparation of the geologic map of the United States. Carrying out these functions required a broad range of activities. These were described by the Director, Major John Wesley Powell, to a Congressional investigating committee in 1886 (p. 89-90) as including: (1) a topographic survey, requiring astronomic and trigonometric methods; (2) a geologic survey, including the collection of fossils, minerals, ores and rocks for laboratory study; (3) the study of economic geology, gold, silver, etc.; (4) paleontologic researches; (5) chemical researches on the constitution of waters, minerals, ores, and rocks; (6) lithologic researches; (7) physical researches related to geology; (8) a graphics division; (9) bibliographical researches; and (10) a division of mineral statistics. The committee also looked into the operation of the Coast and Geodetic

Survey, whose basic mandate involved hydrography. C. A. Schott, H. Mitchell, and B. A. Colonna of the Survey described the range of observations necessary to do this work properly (p. 7-8): triangulation; astronomical observations; leveling; tidal observations; gravity observations; topography; hydrography; and, finally, magnetic observations. Thus in each case doing a good job involved a considerable range of measurements.

When a broad perspective is present a strong scientific underpinning is found to be essential. The research, however, normally represents only a small fraction of the available resources. Geological Survey reports have provided the following rationale (p. 46):

> The principles controlling mineral deposition and the laws governing the occurrence of ore bodies can be satisfactorily determined only as a result of the comprehensive study of many mines and mining camps. This work is beyond the reach of individuals but is appropriate to the national organization. The application of the principles to particular ore bodies and camps is quite within reach of the individual mining engineers charged with development work.

Also:

> The broad and searching observations which should accompany every piece of good economic work comprehend data that are eventually combined in the construction of new scientific hypotheses, some of which, as more observations accumulate, grow into established laws or principles that are in turn of the greatest practical consequence. Thus the detailed studies of the metalliferous deposits in one region or another bring to light evidence from which to determine the genesis of the ores and the modes or conditions of their occurrence.

Furthermore, Major Powell's statement before the Congressional hearings in 1885-6:

> There are many investigations that may not at first seem to lead to economic results, but which ultimately and indirectly are of importance even for economic purposes. The scientific man, especially the geologist, for reasons which I have heretofore set forth, has to do with a vast complexity of problems. To select a part of these problems and work upon them may not lead to substantial results when other problems are neglected that have relation to the first. The whole body of research in geology has a very important practical value, because geologic investigation reveals the wealth buried beneath the surface of the earth. Sound geologic conclusions cannot be reached by following a few narrow lines of investigation, but all such lines of research must be followed that each may shed light upon the other. Unless this principle is fully recognized, a geologic survey might lead to conclusions of no value to the people at large, or conclusions might be reached so erroneous as to be misleading. It therefore often happens that in determining to inaugurate investigations in a particular line the one question asked is, "Are we likely thereby to discover facts that will shed light upon the general problems of geology?" feeling assured that ultimately all such research will be of economic value.

The contrast between the increase in knowledge and tangible practical applications as a factor in Federal support of research can be seen in the history of the Naval Observatory (the following history is given in Weber, 1926). John Quincy Adams, in his first message to Congress as President, December 6, 1825, urged the establishment of an astronomical observatory. Proposals for astronomical measurements had been made to Congress from 1809 on till 1824, the main protagonist being an amateur astronomer,

William Lambert. From 1825 to 1842, as President and Congressman, Adams continued to propose a national astronomical observatory. His reasons are summarized in a statement of 1840:

> The express object of an observatory is the increase of knowledge by new discovery . . . . There is no richer field of science opened to the exploration of man in search of knowledge than astronomical observation; nor is there, in the opinion of this committee, any duty more impressively incumbent on all human governments than that of furnishing means, and facilities, and rewards, to those who devote the labors of their lives to the indefatigable industry, the increasing vigilance, and the bright intelligence indispensable to success in these pursuits. (p. 7)

The Secretary of the Navy, asked for his opinion in 1830, stated:

> 1st. In a national point of view, as it would furnish the means of making such observations as would enable astronomers to ascertain or calculate the positions of the heavenly bodies at any time without being dependent on other nations for the same; and would be, moreover, a fixed point to whose meridian (commonly called a first meridian when used for geographical purposes) terrestrial objects may, with certainty, be referred, as far as respects their longitudes.
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> 2d. It would, furthermore, be desirable in a scientific point of view, as it would present the means of comparing certain astronomical results, for the purpose of determining the figure of the earth and improving theories relative to the motions of the planetary bodies. (p. 6)

Subsequently, in 1835, the Secretary of the Navy stated:

> "A national observatory, although not immediately necessary to the defense of our country, is remotedly so; and, considered with reference to the bearing it would have upon our Navy, our commerce, and scientific pursuits, it assumes an importance worthy of the consideration of Congress."

These appeals which focussed on the purely scientific merit of an observatory, had no result in Congress. It has been proposed that the opposition to an observatory in this period was largely due to political enmity to Adams, though it appears to me that this in itself would have been insufficient if a compelling need were seen. A national observatory was finally established, but only by a back door method. A Navy Depot of Charts and Instruments had been established in 1830 for the purpose of providing reliable charts and instruments to Navy ships. In 1834 Lieutenant Charles Wilkes took charge of the Depot and, at his own expense, erected a small observatory. In 1842 a permanent building for the Depot was finally authorized, and the functions for the Depot included astronomical observations. The justification was the tangible national need of instrumentation for Navy ships.

Metrology, the provision of accurate and standard weights and measures, has been a concern of the Federal government from its inception. Over the years various Congressional acts dealt with specific aspects of standardization as specific needs arose. With increasing complexity in industry and commerce the need for stable and accurate standards became more and more apparent. American scientists, merchants, manufacturers, and even government officers, who needed standardization were required to send their instruments and apparatus abroad. This state of affairs finally led to the creation of the National Bureau of Standards

in 1901.* From the beginning the service function of the Bureau was a major part of its work. The functions of the Bureau were defined in the act setting it up as (Weber, p. 76):

> "the custody of the standards; the comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the government; the construction, when necessary, of standards, their multiples and subdivisions; the testing and calibration of standard measuring apparatus; the solution of problems which arise in connection with standards; the determination of physical constants and the properties of materials, when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere."

The activities of the Bureau were always broadly based, and normally included a research component. In 1925 these activities were described as (Weber, p. 79-80):

> "weights and measures work; electrical work; gas engineering; safety engineering; study of radioactivity; X-ray measurement; atomic tests of measurements; heat and power measurement and research; investigation of fire-resisting properties of building materials; study of automotive power plants, fuels and lubricants; work in optics; work in chemistry; work in mechanics; sound measurement; study of structural and engineering materials; study of miscellaneous materials; work in metallurgy; work in ceramics; work in glass; standardization of equipment; and building and housing service. The Bureau also conducts, outside of office hours, classes for the instruction of its personnel, but this instruction is not one of its prescribed functions."

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*The facts regarding the Bureau of Standards are taken from Gustavus A. Weber, "The Bureau of Standards", Baltimore: The John Hopkins Press, 1925.

The mode of operation involved an awareness of the benefits to be derived from contracts and collaboration with other scientists and organizations (Weber, p. 80):

> By its close cooperation with other services of the national government, with state and local governments, and with various scientific, technical, and industrial organizations; by its participation in national and international conferences on standardization and other scientific conferences in many fields; by its collaboration with scientists and experts of such organizations both here and abroad in making tests, comparisons and researches; by the personal studies and observations undertaken by members of its staff concerning methods and results in this and foreign countries; and by affording opportunities for self-advancement and encouraging an esprit de corps among its employees; the Bureau of Standards manages to accomplish a great amount of valuable scientific and technical work which is out of all proportion to the expense incurred therefor.

The justification for its work was in terms of the economic benefits to the economy and to the cost effectiveness of the information provided (Weber, p. 80):

> The Service which the Bureau renders to the national government is of the greatest importance. In its work on specifications, testing, scientific and technical researches, standardization, simplification, and housing, it acts as a great consulting laboratory for the other branches of the government and is instrumental in effecting great savings in government purchases and services.

Thus here again the original motivation was an apparent national need, and the justification for continued operation was the provision of services to the economy.

The impact of the original director in setting the style and atmosphere of an organization can be seen historically in organizations such as the Geological Survey and the Bureau of Standards. A more recent example is the Air Force Office of Scientific Research. Colonel Haywood, who set it up, described his philosophy in the following terms (1954 hearings, p. 611):

> "I hasten to add I was almost alone within the service in my point of view. I fought against in-service research for 2 years in the service and we did none in my office... I made it clear to all my people, civilian scientists as well as the military, that they were being judged on how well they selected outside sources for contract research projects, and how well they followed the contract work. If in doing their job, they had some time for some research themselves, that was all right, but that was not what they were paid for."

More than twenty years after his departure, in 1975, AFOSR remains the only Air Force laboratory which does no in-house research at all. Similarly the National Science Foundation has remained a contract granting and monitoring organization.

To summarize: In all these cases a clear and apparent national need was the motivating factor in setting up the new agency. It was recognized that the needed effort could not or would not be carried out by private individuals or groups. On occasion it was recognized that impartiality and objectivity were an important requirement, and that this could best be achieved by the use of the civil service. The division of

functions involved planning, specification and monitoring by the government, and manufacturing by the private sector. The gathering of information was recognized as necessary both for the solution of problems and as essential input for policy decisions. This research function, however, has always been particularly vulnerable to criticism, and consequently to budgetary cuts, because the connection to the recognized need is not always so apparent. Research has always represented only a small part of the budget and resources. The breadth of interests of a Bureau and its emphasis on application, service, or research appears to have depended largely on its early Director or Directors, who have set the tone which has been maintained often for decades. The new agency, if not independent of a Cabinet Department, appears often to have been put where convenient. The Treasury Department has often been such a host. The Weather Bureau was originally a part of the Army Signal Service because of an Army officer's desire to find new uses for the organization built up during the Civil War. The question of military or civilian organization has often come up. The military represents an easily available, disciplined and organized group prepared to take on whatever functions are required of them. The work of the Bureau often requires a different type of training and personality, however, so that if a scientific or innovative emphasis is needed jurisdiction is often shifted from the military. The 1896 Commission

investigating the Signal Service recommended a gradual change to civilian administration, stating: "The commission do not believe that this work is in any sense military work, or that military discipline and law are necessary to its efficiency. All concur in the opinion that this work is civil work in its nature and character, and that military restraint is not necessary." I may also note that there has been a recurring fear of the potential mischief that could be caused by a powerful, well-organized, well-disciplined group, and a consequent need for restraints on and limitation of authority of this group. The Mansfield amendment in 1969 appears to have been an example of this.

Historical overview: Who performs research?

In the United States up to the end of the nineteenth century research was performed either in governmental laboratories or by private industry, generally with a tangible application in mind. The growth of university research as well as the foundation and growth of scientific professional societies occurred only in the last decades of the nineteenth century. From then until the present the growth of universities, membership in professional societies, and in the published literature has been exponential. It became clear within the past decade that this growth could not continue or the entire world would be peopled

by physicists, for example, and covered over with science literature. Signs of a stabilization of numbers are now in evidence.

At the beginning of the twentieth century the robber barons, beset by social conscience, initiated philanthropic foundations. The Carnegie Institute of Pittsburgh was created in 1896, the Carnegie Institution of Washington in 1902, the Russell Sage Foundation in 1907, the Rockefeller Foundation in 1913. These are only a few examples of a multitude of foundations. Many of these had a research component. The Carnegie Institution of Washington, for example, was set up "to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind". (Encyclopedia Brittanica, article on Foundations, Philanthropic)

By the late 1930's these four sectors of science support co-existed with only slight interchange between them. The universities did basic research, government laboratories did mission related applied research and the related basic research needed for the successful prosecution of their applied research, the foundations worked in special areas such as medical research, and industry did applied research with, generally, very specific tasks, though some laboratories such as General Electric and Bell Telephone allowed their best scientists considerable lati-

tude in exploring new areas. In the post-World War II world, with its acceptance of the necessity of science research for the solution of problems, government has taken a central role in the support of research providing a significant fraction of the funding for universities and industry as well as supporting research in its own laboratories.

The most recent prominent performer of research is the Federal Contract Research Center (FCRC). These are organizations set up and financed by government in order to advise on operational problems. Mitre, Lincoln Laboratory, Aerospace Corporation are all examples of this genre. They are similar in nature to the counsulting firms, such as Arthur D. Little, set up in the 1880's, and to the non-profit consultants, such as the Battelle Memorial Institute. They were originally set up to provide a flexibility in salaries and hiring not available in government laboratories, and to avoid the rigidities and paperwork inherent in government operation. In some cases, as in the contractor operated laboratories of the Atomic Energy Commision, these captive corporations derive their mode of operation from their origin in World War II. They operate under restraints on their non-agency funding. Mitre Corporation, for example, by the terms of its contract with the Air Force, must derive no more than 50% of its funding from other agencies or private sources.

For the DoD in FY 75 the proportion of funding of the RDT&E budget in each category was: in-house, 29.2; industry, 66.0; universities, 2.31; and FCRC, 2.49. The bulk of the funding is thus for industry, with most of the remainder going to in-house laboratories. Universities and FCRC's, taken together represent less than 5% of the funding.

Should research be a part of a product division?

The recent changes as well as the re-organization, re-structuring and re-orientation in store in the immediate future, all have as their objective the inclusion of research as a responsive and subordinate part of a product division. The question has been put by E. Callan, in a letter to Secretary of the Air Force John McLucas, 20 July 1975; as to whether the systems drive the research or the research drives the systems, in the sense of providing innovations and new departures. Clearly the organization of research to respond to (largely) immediate systems needs will be considerably different from one devoted to initiating and suggesting new directions with longer range applications. It is unfortunate that the current situation is one where these two very different types of research are considered to be mutually exclusive, so that one must make a choice between them. Even a brief reflection should be sufficient to convince one that different needs are involved, and that both are needed for the long term health of the nation.

The problem is not a new one. It has been present, probably, from the beginnings of military research. I cite here the comments of Vannevar Bush at a House Committee hearing in May 1[illegible] (Dornick, 1972):

> I put down...two basic principles for successful government participation in scientific research. First, the research organization must have direct access to Congress for its funds; second, the work of the research organization must not be subject to control or direction from any operating organization whose responsibilities are not exclusively those of research.
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> Industry learned a long time ago that it was fatal to place a research organization under a production department. Research and an operating responsibility, such as production or sales, are incompatible. An operating group is under the constant urge to produce in a tangible way, to meet existing standards, and existing schedules. An operating group has neither the time nor the inclination for research. An operating group is judged by production standards. Research, however, cannot be judged by production standards. Research is the exploration of the unknown. It is speculative and uncertain. It cannot be standardized. It succeeds, moreover, in virtually direct proportion to its freedom from performance controls, production pressures, and traditional approaches.
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> It is fundamental, accordingly, that research on military problems should be conducted, in time of peace, as well as in war, in part by civilians independently of the Military Establishment. The armed services exist to fight. It is their primary responsibility to train men, make available the weapons, and employ the strategy that will bring victory in combat. The armed services cannot be expected to be experts in all of the complicated fields which make it possible for a great nation to fight successfully in total war. There are certain kinds of research - such as research on the improvement of existing weapons - which, of course, can be done best by military men within the Military Establishment. The job, however, of fundamental scientific

> research should be entrusted to the civilian scientists who are best trained to discharge it thoroughly and successfully. It is essential that both kinds of research go forward. We have just learned, for example, that one of the primary reasons why German science failed to maintain its superiority over the Allies is because in the early stages of the war German scientists were diverted from fundamental research for concentrated effort toward the improvement of existing weapons.
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> An able research scientist is the product of the intensive and specialized training of many years. The military man, who must acquire many other skills, cannot acquire that degree of specialization and training in science which is essential if broad and important scientific advances are to be made on military matters. Nor is the military tradition or the position of the military man within the services conducive to fundamental scientific research. The scientist must be free from restrictive controls. He must not be under the compulsion to produce immediate results in order to obtain advancement. Moreover there must be parallel research attacks on a great problem by several groups approaching from different points of view. This has been demonstrated times without number in industry and in our own war experience....

A similar comment on military officers in professional positions was made by Professor Asaph Hall in 1899, when the organization of the Naval Observatory was under discussion (Hall, 1899):

> "Of course, a number of the line officers who have been at the Observatory have been able men, who, with time enough given them, could learn anything or do anything. The reason why they did not do well in astronomical work usually was that it took them too far from the profession for which they had been trained."

General Eisenhower, while Chief of Staff in 1946, advocated a separation of "responsibility for research and development from the functions of procurement, purchase, storage and distribution." (Penick, p. 21).

For a military view of the role of research (without qualifying it as typical or not) we may cite Commodore Belknap in 1885 on the Naval Observatory (cited in Science, 1899):

> "It is first of all a naval institution, its astronomical work being, so far as the naval service proper is concerned of a purely secondary consideration. **** If the time has come when the purely scientific side of the institution has outgrown the needs of the naval service the converse is true, namely, that the navy has no need of it or of the scientific staff. If the so-called scientific men of the country thinks that the time has come to apply to Congress for money to build a national observatory the Navy will not stand in their way; only it will take no responsibility for it, and will be glad to see it go to another department of the government, and to be under purely civilian control, including professors with civilian appointments instead of Naval commissions."

In fairness to the Navy it should be stated that the post-World War II Office of Naval Research has been one of the strongest supporters of basic research. It would appear that the Navy, at least, has perhaps profited from some of the lessons of the past. Belknap's suggestion that an observatory which is primarily scientific should go to another governmental department seems to be what is currently happening to the Sacramento Peak Observatory of the Air Force Cambridge Research Laboratories.

These excerpts are sufficient to indicate the need for separation of a research function from a production function. When research is subordinated to applications the tendency becomes one of using the available manpower for the solution of

immediate problems, and meaningful research becomes difficult, if not impossible. It is worth noting that among the commentators above are the successful architect of the major war time research effort leading to weapons, and the successful architect of military victory in Europe.

Who decides? The question of personality types.

Implicit in the question of the coupling of research and applications discussed above are the related questions of who does the research and who decides what research is to be done and how. It should be obvious that one must start with able men in an atmosphere which allows them to function efficiently. Here I cite the discussion by Baxter (1946, p. 7-8) in his history of the Office of Scientific Research and Development in World War II:

> The first requisite of a satisfactory organization of science for war is that it must attract first-rate scientists. One outstanding man will succeed where ten mediocrities will simply fumble. In creative thinking there are no substitutes for imagination and resources. These will flourish only when the scientist has ample funds and a large measure of freedom. At the same time he cannot work alone in an ivory tower. Many of the problems involved must be attacked by teams of men with different skills and angles of approach, and on all of them effective liaison must be provided with the armed services. The organizational problem at this point becomes one of great difficulty. Armies and navies are operated on the principle of the chain of command, not on the principle of consultation and discussion. Their systems are well adapted to the conduct of military operations and to the production and methodical improvement of standardized equipment. They

are anything but favorable to the conditions under which scientific inquiry best thrives, and the reconciling of the two is a matter of the utmost importance.

Here the Germans made almost every conceivable blunder. They were convinced of their ability to win the war quickly, with the excellent weapons they had produced in peacetime. If the war was to be a short one, they needed no great organization for the development of new weapons, no mobilization of their vast resources of scientific personnel, no experiments to ensure the scientist freedom to create within the meshes of their huge military system. German academic scientists could be left to their peacetime researches with the expectation that these would prove of value to the State after the war, helping in the reconversion of industry and in the keen international competition of the postwar years. It has been suggested that the Germans excluded academic scientists from war research because they did not believe them sufficiently imbued with Nazi doctrines, but of this we cannot yet be certain.

German war research in the early years of the war was therefore with few exceptions confined to the laboratories operated by the armed forces and those of the war industries. What fundamental research had been carried on in them in peacetime was greatly curtailed if not entirely dropped. By Hitler's orders basic research on radar, for example, was stopped in 1940, and was not renewed until 1942. The heavy hand of bureaucracy forced industrial as well as government laboratories to concentrate their efforts on the improvement and testing of existing weapons.

The fixed belief in a short war had serious effects over the whole field of German industrial production. In war research it cost Germany the lead acquired in peacetime. Industry in America had long since learned that to subordinate the research staff to the production department is the shortest road to failure. Germany made this faulty conception the basis of her system. Not only were her industrial scientists deprived of the cooperation of academic chemists and physicists, diverted from fundamental research and placed under the control of production men far down in the hierarchy of the war effort; they were not furnished with effective liaison with the armed services. They were given specifications and told to fill them, but were not afforded opportunity for that constant and fruitful collaboration with Army and Navy officers which contributed so markedly to the

> success of the British and American war effort. Under German regimentation there was no room for such an uprush of useful ideas from industry as took place in the English-speaking democracies. A representative of a great German electrical firm testified bitterly that only one of their engineers had been permitted to see in actual operation the best of the radar sets they manufactured.

In a similar vein Detlev Bronk in 1953 (cited in Abelson and Abelson, 1975) discussed the importance of science for all of society. He then said:

> "This is justification for inclusion of some who are neither scientists nor professional scholars in any field among administrators and trustees who play a powerful role in guiding the affairs of science and its uses. It does not justify their lack of understanding of science and the conditions under which it can flourish..."

A bitter comment on the difficulties of getting first-rate scientists to work in a command structure where authority is in the hands of people with different goals and personalities was made during Congressional hearings in 1954 by Mr. John W. Marchetti, a former Technical Director of the Air Force Cambridge Research Center (Penick, p. 243-244). On being asked by Mr. McCormack on whether one could place military personnel in a research laboratory, Marchetti replied:

> I do not believe you can. When you do you wind up with a second-and-third-grade laboratory. Generally speaking, the Air Force laboratories - and I will take Wright Field as an example; it is one of the oldest of the Air Force laboratories - you will find there that they have groups on propulsion, groups on electronics, groups on antennae, and you will find the chief of these various laboratories is either a captain, a major or a colonel. In some cases these people are competent to hold their jobs, but there are very few such cases.

Down in the fine print you will find some civilian. He is the fellow that is really running the show, but he is a second-rater or a third-rater because no first-rate technical man will go into a laboratory structure where the chief of the laboratory is a titular military man and he has to carry the responsibility without having any of the authority.

This is the reason why the military laboratories with that policy are dedicated to be second-and third-rate laboratories. No competent people will go into such an organizational structure. It is the continual cry on the part of the military that they cannot entice capable technical people to work for them. But this is utter foolishness when they put captains and majors or even full colonels in there as superiors just by virtue of their military rank. That is the heart of the problem. That is the reason why Wright Field is not a good laboratory. At Cambridge this did not obtain prior to the arrival of the last commander.

I had hoped that the Air Force would see the light, would go and change gradually, because it has to be a gradual process. I had hoped that the Air Force would change the policy to fit the Cambridge pattern, where a fair amount of authority - and let me even put it this way, just plain ordinary courtesy and equality was allotted to the technical civilians. If they had changed their other laboratories to follow the Cambridge pattern, we would have a healthy condition.

I find, however, after General Maude came in and the conversion took place, Cambridge was made to follow the pattern that was established in the other laboratories where the control was fully military and the scientific people were asked to work for a continually changing, inept and sometimes pretty irresponsible military organizational structure. I think that is the very heart of the problem.

The interaction between civilian and military administrators can be seen in the difficulties which arose in the early 1950's at Rome Air Development Center and the Cambridge Research Center, both derived from the Watson Laboratories, organized in early

1945 to provide the Air Force with electronic systems.* In both cases a major part in the organization was played by an individual, originally a wartime officer, who then became the civilian technical director. The chain of command involved an active service officer with his deputy, also military, and then the civilian technical director. In both cases for some time the system worked well with the civilian essentially responsible for the operation of the laboratories. Because of the rotation system for the military new commanders would arrive from time to time. Difficulties arose in both cases when the new commander asserted his command prerogatives, and this was not accepted by the civilian who had been running the operation for some years. It has been pointed out by a number of commentators that the military atmosphere involves hierarchy and that advancement is based on the ability to command. It appears to have been accepted by the military commanders that these aspects of the military system also were applicable to the research and development laboratories they were assigned to. Thus, Colonel Heavner, describing his first days at RADC, states that the civilian director threatened to resign if the Colonel interfered with his

*The information on these difficulties is derived from the Hearings before the Subcommittee on Military Operations, Committee on Government Operations, House of Representatives, 83rd Congress, Second Session, June, 1954, "Organization and Administration of the Military Research and Development Programs".

direction. Colonel Heavner, after checking some of the director's statements, decided he could not be trusted, reported this to his supervisor, adding:

> "... and, from where I sat, if he was objecting to being managed and they wanted me to manage the laboratories, I would relieve him as the technical director. This was agreed to ..."
>
> (Hearings, p. 312)

Dr. O. G. Haywood, formerly a Colonel who had set up the Air Force Office of Scientific Research, on being asked whether there was a tendency for the military to expand its control over technical decisions and operations in research laboratories, stated (p. 602):

> "My reaction to that is, good. That is a function of management - to control, and if it is a military organization the military should control the technical operations. I do not make a distinction in my mind as to whether that control is by a man in uniform or not. But the research and development organization in all of our services is part of the military structure. Even if it were all civilian I would say the same thing, that it is part of the Military Establishment. And there should be military management of it. Again I put the "military" in quotes, and mean management by persons, in uniform or not, who are responsible ultimately to the Secretary of Defense, and through him to the Congress."

Taking all factors into account a pattern begins to emerge. The laboratories are set up and grow under one individual. The original thrust for Rome Air Development Center and the Cambridge Research Center was the maintenance of an existing pool of talent for the solution of clearly visible problems present at the end

of the war. The laboratories expand under the direction of the strong willed individual who set them up. Over a period of years the rotation system for commanding officers produces a succession of commanders who have more or less influence on what is done in the laboratories, but the basic direction remains in the hands of the original civilian, who, because of his part in the setting up and expansion of the laboratory, feels entitled to its direction and also has a considerable emotional investment in the laboratory. At some time, one of the commanders, either on his own initiative or at the behest of his superiors, exercises the military command role - he insists on the hierarchical organization, on his prerogative to command and control, and on the obedience of lower levels to tasks imposed from above. In the cases of RADC and CRC it is not clear from the testimony whether the decision to assume control by military officers came from the higher levels, though it is clear that these actions would not have been taken without approval from these levels. In any event it seems almost inevitable that because of a succession of commanders (in one case, about 12 in 9 years) at least one at some time will attempt to establish control. The result is the loss of some, at least, of the more independent civilians and their replacement by men more willing to command or be commanded, depending on their superior's wishes. The long range

effects on a laboratory can only be the elimination of independence and autonomy, and the establishment of more directly mission related tasks and shorter term projects, the latter because they must adapt constantly to new sets of officers with new goals. Science, in short, becomes a casualty. It is my own belief that it has not been sufficiently recognized that the root of the problem lies in basic personality differences between people seeking new knowledge and those seeking to apply knowledge. In some unpublished notes I have discussed some of the problems resulting from this. I cite here some relevant portions of these notes: We may note to begin with the difference between practice and knowledge disciplines. The difference is that practice is problem-oriented, not interested in depth, looks for immediate solutions, and is thus time oriented as well. If a problem can be solved without knowledge, fine. Anything involving additional time or energy detracts from the orientation of immediacy. Thus problem-orientation tends to be ad-hoc. Knowledge orientation, on the other hand, has no sense of time limit, wishes to explore ramifications, and explores tangential aspects of a problem. It may be as narrowly focussed as practice, but without time limits. It looks for causes, and effects are only important as they lead to causation.

Practice disciplines are thus horizontal, drawing from many

fields of experience or knowledge, but only to the extent necessary to help solve the problem. Knowledge disciplines are vertical, going into depth in a single area. Experience provides facts which are to be ordered and systematized - any set of facts which provides this is equally important. The fact itself is not important - the system which coordinates these facts is what counts. This is in contrast to the practice-man, for whom the specific, particular fact is the focus, and the coordinating system may or may not be useful, but is in any event not essential, just as a specific fact is not essential for a theory, since many others may serve equally well to validate the hypothesis.

Thus we may expect difficulties between people in knowledge disciplines and practice disciplines. These will be reflected in the personalities in two ways: (1) the image of the subject determines the personality type attracted to it, and the socializing process involved in the professional education will tend to fix and stabilize this personality type in the particular profession; and (2) if the personality types for the two disciplines are sufficiently different then (a) communication is difficult or impossible, and (b) frictions may arise which can vitiate any constructive working together. From the descriptions above it seems likely that both will happen when we are confronted with practice-knowledge pairs.

It may be noted that in the selections I have given it is clear that whether a research laboratory succeeds or not is dependent on the extent to which these people differences have been taken account of in the organizational structure.

What is the environment for successful research?

The requirements which government scientists have stated to be necessary for successful research have remained remarkably constant over the past century and a half. These have been summarized by Penick (p. 5-6) as:

(1) The need for long-term support.

(2) The need for flexibility in objectives.

(3) Freedom to publish.

(4) Access to the international scientific community.

(5) The need to improve the position of the professional scientist in American society.

The list bears many similarities to the conditions found to foster productivity of research scientists by behavioral scientists in recent years. I cite here a portion of the Table of Contents of the book "Scientists in Organizations" by Pelz and Andrews (1966) which summarizes their findings:

> FREEDOM: Is coordination compatible with freedom? Best performance occurred when both were present.
>
> COMMUNICATION: Effective scientists both sought and received more contact with colleagues.

DIVERSITY: In both research and development, the more effective men undertook several specialties or technical functions.

DEDICATION: Several simple questions showed that high-performing scientists and engineers were deeply involved in their work.

MOTIVATIONS: Among various motives characterizing high performers, an outstanding trait was self-reliance.

SATISFACTION: Effective scientists reported good opportunities for professional growth and higher status but were not necessarily satisfied.

SIMILARITY: Colleagues of high performers disagreed with them on strategy and approach but drew stimulation from similar sources.

CREATIVITY: Creative ability enhanced performance on new projects with free communication but seemed to impair performance in less flexible situations.

My final citation is from Vannevar Bush, in "Science - The Endless Frontier", (cited in Penick, p. 191-192) contrasting the conditions for effectiveness in pure and applied research:

> Scientific research may be divided into the following broad categories: (1) pure research, (2) background research, and (3) applied research and development. The boundaries between them are by no means clear-cut and it is frequently difficult to assign a given investigation to any single category. On the other hand, typical instances are easily recognized, and study of them reveals that each category requires different institutional arrangements for maximum development.
>
> Pure research is research without specific practical ends. It results in general knowledge and understanding of nature and its laws. This general knowledge provides the means of answering a large number of important practical problems, though it may not give a specific solution to any one of them. The pure scientist may not be at all interested in the practical applications of his

work; yet the development of important new industries depends primarily on a continuing vigorous progress of pure science.

One of the peculiarities of pure science is the variety of paths which lead to productive advance. Many of the most important discoveries have come as a result of experiments undertaken with quite different purposes in mind. Statistically it is certain that important and highly useful discoveries will result from some fraction of the work undertaken; but the results of any one particular investigation cannot be predicted with accuracy.

The unpredictable nature of pure science makes desirable the provision of rather special circumstances for its pursuit. Pure research demands from its followers the freedom of mind to look at familiar facts from unfamiliar points of view. It does not always lend itself to organized efforts and is refractory to direction from above. In fact, nowhere else is the principle of freedom more important for significant achievement. It should be pointed out, however, that many branches of pure science increasingly involve the cooperative efforts of numerous individuals, and expensive capital equipment shared by many workers.

The preparation of accurate topographic and geologic maps, the collection of meteorological data, the determination of physical and chemical constants, the description of species of animals, plants, and minerals, the establishment of standards for hormones, drugs, and X-ray therapy; these and similar types of scientific work are here grouped together under the term background research. Such background knowledge provides essential data for advances in both pure and applied science. It is also widely used by the engineer, the physician and the public at large. In contrast to pure science, the objectives of this type of research and the methods to be used are reasonably clear before an investigation is undertaken. Thus, comprehensive programs may be mapped out and the work carried on by relatively large numbers of trained personnel as a coordinated effort....

Applied research and development differs in several important respects from pure science. Since the objective can often be definitely mapped out beforehand, the

> work lends itself to organized effort. If successful, the results of applied research are of a definitely practical or commercial value. The very heavy expenses of such work are, therefore, undertaken by private organizations only (sic) in the hope of ultimately recovering the funds invested....
>
> The distinction between applied and pure research is not a hard and fast one, and industrial scientists may tackle specific problems from broad fundamental viewpoints. But it is important to emphasize that there is a perverse law governing research: Under the pressure for immediate results, and unless deliberate policies are set up to guard against this, applied research invariably drives out pure.
>
> The moral is clear: It is pure research which deserves and requires special protection and specially assured support.

If the above requirements for successful research are absorbed and understood then there should be no difficulty in diagnosing the causes of the complaints about governmental military research laboratories which were collected by a Congressional sub-committee in 1954:

> Reported Problems in Military Research and Development Programs.
>
> I. Civilian scientists in military research and development centers are reported to be generally dissatisfied with military domination and administration.
>
> II. Civilian scientists are leaving military research and development centers.
>
> III. When a military organization is imposed on a research and development program there is a tendency for the military to expand its control over technical decisions and operations in the research laboratories.
>
> IV. With a few notable exceptions, military research and development officers are not scientists who command the respect of the civilian scientists.
>
> V. The policy of rotating assignments for military officers militates against the retention of officers who in some cases have the training, talents, and disposition to guide scientific research centers.

VI. Research centers often are organized and administered as military organizations with the attendant restrictive forms, procedures, regulations, and military discipline which do not provide the optimum climate for research work by civilian scientists.

VII. The lack of either a definite or consistent policy for organizing and administering research and development centers leaves each center at the mercy of each change in commanding officer and Executive. This creates an instability with no assurance that even the well-run research and development center will not become, with a change of officers, an unbearable situation.

VIII. Several outstanding civilian scientists who have been associated with military research and development programs are reported to be in favor of changes in the governmental organization and administration of these programs.

IX. The funding of research and development is confused when handled with military budgets. Direct research and development costs are justified to and appropriated by the Congress as such. However, this does not give a true picture of the actual total cost of military research and development programs inasmuch as there are substantial indirect costs arising from military support functions in the form of pay for uniformed officers, provision of capital facilities, and certain maintenance and operation expenditures.

In this connection, it is reported that it is often felt necessary to build up a research and development center with such support functions in order to make it "respectable" in terms of size and complexity as a command for a colonel or general. This, in turn, sets off a vicious cycle in that the existence of military support elements becomes a further excuse for military domination, more officers, regulations, etc.

<u>Gresham's law for research: Applied drives out pure research.</u>

I have noted elsewhere Vannevar Bush's comment, that "under the pressure for immediate results, and unless deliberate policies are set up to guard against this, <u>applied research invariably drives out pure.</u>" Essentially the same comment is made by

Downes (1967), that certain types of activities "tend to be eliminated when operations are trimmed to a bare minimum. These include long-range planning, basic research, operational research, and experimental innovation". As an example of this I cite the cuts in the U.S. Geological Survey budgets in the early 1890's (Inst. Govt. Res., 1918). Because of a general tendency to reduce appropriations as a result of the economic depression of the period. Over a four year period the total budget was cut from about $879,000 to about $488,000. Proportionately, however, the heaviest reductions were made in the research budget, which was comparatively small to begin with. Thus paleontological research was reduced from $40,000 to $10,000, and chemical and physical researches from $17,000 to $5,000. Similarly, in the present (1975) Air Force personnel cuts in the laboratories the entire cut of 385 is made by the elimination of one laboratory involved in basic research (ARL) and the dismantling and re-structuring with concurrent RIF of the other Air Force laboratory which has traditionally been supported by basic research funds (CRL).

It might perhaps seem strange that a portion of the work which involves only a very small fraction of the personnel and resources of the Bureau should be singled out for heavy demolition. While I do not have the figures for the Geological Survey

for the 1890's, the proportion of research personnel is unlikely to be much different than in 1917. At that time the section devoted to physical and chemical researches consisted of 14 people, compared to 934 for the entire survey. The research budget in 1890 was less than 8% of the total. Similarly, in 1975, the personnel of Air Force laboratories totalled of the order of 10,000, including about 30% military. Of the approximate total of 7,000 civilians something like 650 (counting all in ARL and half in CRL) were involved in basic research. Thus approximately 10% of laboratory personnel and only a minuscule percentage of total Air Force personnel (650 research personnel out of a total of 287,000 civilian personnel at the end of FY75, or approximately 0.2%) and budget were involved in what might, somewhat elastically, be called basic research. Yet the personnel cut may be estimated (counting all of ARL and half of the CRL cut) as something like 285 of this 650, or over 40% of those involved in basic research.

The reasons for this are not difficult to find. Government research is always set up for the solution of specific problems related to recognized national needs. Those actually attempting to solve these problems find that there is always missing data or theory which is needed and the basic research is designed to fill this gap. These basic data, however, are not as visibly

or as tangibly related to the underlying need as the applied research. In a period of contraction the easiest focus for cuts is on these seemingly unrelated studies. The cry for relevancy then arises. Some excerpts from the minority report on the Coast and Geodetic survey by Congressman Herbert and Morgan in 1886 can be used to illustrate this (U.S. Govt., 1886):

> The real scientists on this subject of nautical maps are educated sailor-men, naval officers, who everywhere the world over, except in the United States, execute or control the execution of coast surveys. So far as the testimony before us goes, all this class of scientific men, or at least a decided majority of them, agree that the topography of the Coast Survey is unnecessarily elaborate and expensive. The scientists who applaud this extensive and elaborate topography we understand to be generally professors in colleges, great mathematicians, astronomers, geodecists, and electricians. These are delighted with the work executed in their several fields by the Coast Survey, while naval officers are disappointed that so much money has been expended in matters other than hydrography, and so much time has elapsed while the survey of the coast of the United States is yet uncompleted.
>
> (p. 68)

> In another respect the Coast and Geodetic Survey seems to have been more careful to adhere to scientific methods of operation than to make maps acceptable to the sailor.
>
> (p. 72)

> The undersigned do not doubt the utility of a thorough and scientific geological survey. We admit also that each of the monograms and bulletins published by the Survey may have its uses but, at the same time, it seems clear that this work promises to be very expensive, and we believe it ought to be curtailed. It is, we think, passing the bounds agreed upon by all the witnesses who have testified before the Commission - namely,

> that Government should not do such scientific work as can be done by individuals. Paleontology appears to us to come within this category. It is true that this was mentioned in the act of 1879; but it is also true that Congress did not then expect such a lavish expenditure of money as has followed.
>
> (p. 88-89)

> It probably is true that much of this work, as contemplated, if not done by the Government will not be done by private enterprise, at least for many years to come. But this is not deemed to be of itself sufficient reason why the Government should embark upon it. All knowledge is desirable, but there seems, at present, to be no limit to the field of possible human attainments. Government cannot explore all this region, and it would appear to the undersigned that when Congress is asked to increase still further the amount of its expenditures for a geological scheme which refuses to be limited by our laws or our territory, it is not sufficient inducement to say, as Major Powell says, p. 1075, in answer to Professor Agassiz, that "great scientific men, like great statesmen and great men in all departments of society, clearly recognize the fact that knowledge is a boon in itself and in its utilitarian consequences alike - that wisdom is exalting and knowledge is power". Like private persons, Government should count the cost of an undertaking. And if it is clear that when we shall have collected rocks and fossils, and placed them, together with maps exhibiting the geographic distribution of geological formations, where they will be accessible to scientists, the latter will not study and discuss them, this would seem to constitute grave reason why Government should not undertake it.
>
> (p. 90)

Another typical example of the objections of Congress to research can be seen in the following description of the factors which led to a Congressional investigation of the Coast Survey in 1842 (Weber, 1923):

> Notwithstanding this extraordinary accomplishment under the difficulties that had been placed in the way of the Coast Survey, clamors arose in Congress against the administration of that bureau. Dissatisfaction was expressed with the progress made. The alleged slow progress was ascribed to an unnecessary refinement in the process employed. The results were claimed to be inadequate to the expenditures.

The result of the investigation was a complete endorsement of the principles on which the survey had been conducted.

In summary: basic research tends to enter the picture as background information needed for the accomplishment of tasks with visible, tangible applications. In hard times this lack of apparent relevancy leads to cuts first in basic research. The effort at any time expended on basic research is always a minuscule fraction of the total effort and a small fraction of the research effort. Thus what happens is similar to the fate of a well-known American minority: last in, first out. In somewhat different vein, the New Testament comment is apropos: "Even from him that hath not shall be taken away."

What fraction of our resources should be allocated to basic research?

The question of an adequate and appropriate allocation of resources to basic research is a difficult one to answer. Factors entering into such a decision would include: the urgency of other priorities, i.e., the extent of crisis in our society; the state of the economy, that is, what base of revenue are we starting

from; the availability of trained and experienced personnel; and our competitive position in particular areas. This should be seen as only a partial checklist. I propose here to discuss some of these factors in terms of past history and experience. Most of the data for recent years is taken from the reports of the U.S. Government's Commission on Government Procurement, December 1972.*

Government support of research for national needs goes back almost to the beginning of our Federal system. Before World War II support of R&D was less than one per cent of the Federal budget. During the war years, as was to be expected, this support increased dramatically. The period of the 1950's was one of increasing investment in R&D, reaching a peak of over 12 per cent of the budget in 1964-1965. The greatest fraction of this came through the Department of Defense. It should have been clear that this growth could not continue either unchecked or unchallenged. A symptom of discontent was the 1962 Congressional requirement that from 1963 on the research, development, test and evaluation portion of the Defense budget must be annually authorized (Penick, p. 45). As often happens with people, the real problem seems not to have been articulated. Rather, tangible foci of discontent were found: in 1964, the geographical distribution of research contracts; in 1965, DoD involvement in social

*In the following a page number without other identification will refer to these reports.

science research; chemical and biological warfare research; and finally, in 1969, the question of relevancy. Federal support for R&D declined from 12.6% of the budget in 1965 to 6.4% of the budget in Fiscal Year 1972 (p. B-5). The decline has been a continuing one. In constant dollars, support for basic research in 1975 is expected to decline by 8% from the 1974 level, the sharpest percentage drop ever recorded by the National Science Foundation (NSF figures cited by Wu, 1975).

What would, in fact, be an appropriate fraction of the total budget to spend on research and development? We can estimate this in several ways. Private, for-profit, professional service firms derive about 3% of their revenue by the provision of research and development (p. A-97). Industrial firms spend between about 4% and 9% of their total sales on research and development, depending on the level of competitiveness in the area (p. B-38), with the sole exception of major contractors for DoD, who spend less than 2%. These contractors, however, include in the cost to the government the cost of independent research and development (IR&D), bids and proposals (B&P), and other technical efforts (OTE), and these are of the order of 4% of total sales (p. B-31). The cost to the government of this effort in recent years is of the order of $1 billion, with the DoD share of the order of $700 million (for 1970 and prior years see p. B-31, for FY 75, see Aviation Week and Space Technology,

December 1, 1975, p. 22). Thus all of these different approaches lead us to an estimate of, typically, 4% of the total budget or sales, or, if competitive factors are present, a greater percentage up to of the order of 9%.

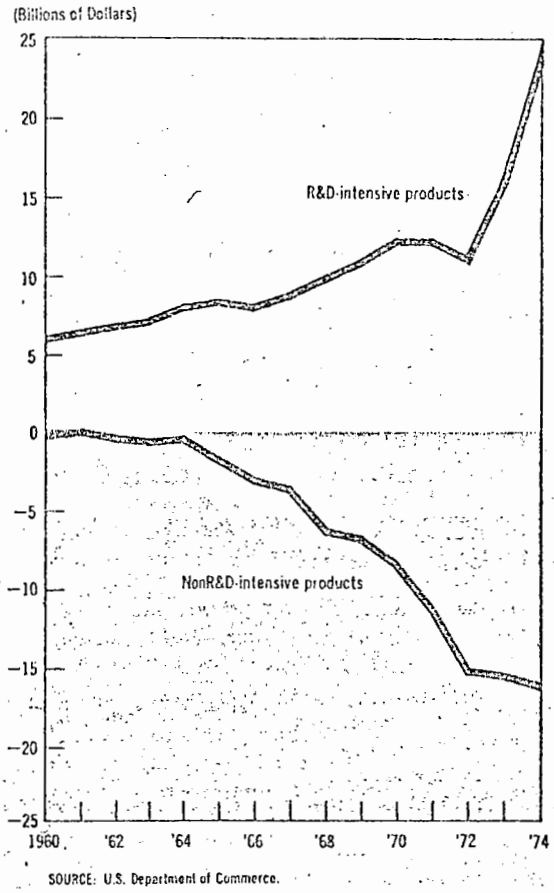
What fraction of the R&D budget should go to basic research? In Fiscal Year 1971, 13.7% of the total governmental R&D budget went to basic research (derived from Table 2, p. B-11 for this and subsequent figures). The DoD percentage was 3.5%, about one-fourth of the overall percentage. The figures for NASA and HEW, respectively, were 21% and 27%. If we consider that NASA and HEW were dealing with problems for which solutions had not yet been found, then this emphasis on basic research becomes comprehensible. Viewed from these terms it would appear that DoD has become enmeshed in solutions (hardware is always much more expensive than the basic research which led to it) and has given up or lost its innovativeness and potential for the future.

This is perhaps the place to note the importance of competitiveness in determining the percentage spent on basic research. The largest percentage in industry is that for the drug industry, highly competitive and dependent on a continuing development of new products for survival. A comparison of the balance of trade for different industries with their R&D expenditures (p. B-63) shows that the higher the R&D expenditure the greater the trade

balance. The empirical evidence then strongly suggests that in a competitive situation R&D is not simply a luxury but is an absolute necessity. One may then ask whether our defense is currently so strong and impregnable that we can reduce our innovative efforts below even the weak 1971 position.

We may ask what an appropriate percentage for in-house work might be. Considering only agencies with $100 million or more R&D funding in Fiscal Year 1970, we find ratios ranging from 1% (AEC) to 74% (Agriculture) (Table 2, p. B-14). Of the ten agencies in this class, three have a percentage less than 10: AEC, 1; NSF, 5; and OEO, 6; four have a percentage from 20-30: Transportation, 20; HEW, 20; NASA, 26; and DoD, 27; and three have a percentage greater than 60: Interior, 63; Commerce, 72; and Agriculture, 74. Of those with low percentages, AEC appears to be almost a historical accident - laboratories set up during the war under contract were maintained in this manner after the war; the National Science Foundation was set up specifically as a granting agency whose primary clients were the universities and whose functions included the training of students; and the OEO (now essentially defunct) was set up to solve a social problem with a sense of wartime urgency. The agencies in the middle have developed their programs largely since the war. At least two of the three agencies with high percentages have histories of research going back to the last century or the first years of the present century, and have historically operated primarily

U.S. Trade Balance in R&D-intensive and NonR&D-intensive Manufactured Products, 1960-74



SOURCE: U.S. Department of Commerce.

in-house. There is no continum of percentages, and experience here, without delving in more depth, is no guide. We shall have to look to other criteria to help us decide.

Finally, I will simply note the in-house percentage for different categories during Fiscal Year 1970 (p. B-11). These are: basic research, 31.9%; applied research, 38.8%; and development, 18.9%. Clearly, in any discussion of appropriate percentages we shall have to take account of the category of research as well.

To summarize: an appropriate level of support for R&D is of the order of 4% of the total budget or sales for relatively non-competitive situations. As the competitiveness increases the R&D expenditure should also increase, perhaps even doubling or more this 4% figure. The fraction of this going to basic research will depend on the novelty of the problem and the need for innovation and imaginativeness. For a highly competitive situation this fraction is more likely to be nearer 25% than 5%. Finally, the ratio of in-house to out-of-house funding will depend on the category of R&D, with greater in-house funding, by a ratio of about 2 to 1, for research as opposed to development.

THE DEFENSE DEPARTMENT AND RESEARCH

The current position of basic research in the Department of Defense.

The present position of the Air Force with regard to basic research can be deduced from the testimony to the House Committee on Appropriations.* The fraction of costs through the life cycle of a typical weapon system is given as 3% for the validation phase and 12% for full-scale scale development, the two categories together being the RDT&E phase of the program. If, as seems likely, the validation phase includes research and exploratory development, the figure seems somewhat lower than might be expected from other areas. This may be accounted for if we assume that this estimate is for a particular system and does not include false starts.

The fraction of RDT&E resources going to research can be derived from two sets of figures which do not give precisely the same answer. If we use the fraction in 6.1 (research) funds (p. 278) then the percentage varies from 2.06% to 2.72%, depending on whether we use the R&D total or the program total as a base. In either case it is below 3%. What should be a similar set of figures is subsequently given for FY 74 through FY 77 for costs in various RDT&E categories (p. 364, also p. 522). I

*"Department of Defense Appropriations for 1976", Hearings before a subcommittee of the Committee on Appropriations, House of Representatives, Ninety-Fourth Congress, First Session. Part 4: Research, Development, Test and Evaluation. U.S. Government Printing Office, Washington, 1975.

derive from these the following percentages for research for the four fiscal years given:

FY 74	3.71
FY75	3.57
FY76	3.32
FY77	3.22

It is clear that the trend of Air Force thinking leads to a significant drop in the research share, of more than 10%.

The figures given at the hearings also allow us to compare the relative importance of research for the three services. The following table gives the research (6.1) funding for the four fiscal years as a percentage of the total RDT&E funding:

Fiscal Year	74	75	76	77
Army	3.98	4.20	3.82	3.56
Navy	4.22	3.89	3.73	3.56
Air Force	2.54	2.42	2.25	2.16

The Air Force percentage is consistently of the order of 60% of the Army and Navy percentages. It is also interesting to note that the FY 77 percentages for Army and Navy are the same. If it is not coincidence one could infer that a ceiling was placed on research spending by higher authority, whether in DoD, OMB, or somewhere else. The figures alone do not enable us to judge between these various possibilities.

It has been argued that the in-house share of funding should be 30%, the remainder going to industry and others. The hearings include data from which of the fraction of the RDT&E dollar being used in house can be derived (p. 522). I present here the percentages for in-house, industry, the universities, and Federal contract research centers, for FY 74 through FY 77:

Fiscal Year	Percentages			
	In-house	Industry	University	FCRC
74	29.0	66.1	2.44	2.47
75	29.2	66.0	2.31	2.49
76	25.6	70.1	2.05	2.24
77	24.1	71.7	1.99	2.23

It is clear that the primary result of the planned changes are the shift of about 5% of the RDT&E budget from in-house laboratories to industry. No justification for cost-effectiveness or any reason other than a change in in-house to industry ratio is given for this shift.

It might be argued that the laboratories have not properly supported the mission. The laboratory utilization study considered the question of the need for in-house laboratories. Dr. Currie stated in this connection (p. 401):

> The study encompassed 47 laboratories in the three Services that employ approximately 58,000 people, most of them civilians. The question of need was approached from the first principl.: Could the Services operate

[illegible] the in-house laboratories? Because of the [illegible] combination of technical expertise, access [illegible] privileged military and industrial information, [illegible]ity with mission area problems and impartiality which in-house laboratories alone possess, the [illegible] was found to be a strong "No." One of the [illegible]portant roles which in-house laboratories should [illegible] providing technical input to the important [illegible] planning function, a role which requires the [illegible] attributes for effectiveness. In addition, the [illegible]ility of the laboratory personnel to the Services [illegible] in-house laboratories a vital source of short- [illegible] quick-reaction technical support. On a more [illegible] level - but an increasingly important one - the [illegible] provide resources needed by the military [illegible] where industrial interest or capability is [illegible]. Finally, the very existence of the in-house laboratories as an alternative source of technology [illegible] industry to perform at its best. Clearly, if they are doing or can do these jobs, we need the in-house laboratories.

Personal visits by my staff during the past year to most of the laboratories confirm that, at their best, the laboratory personnel are highly qualified, are engaged in work that is necessary, appropriate and vital, and maintain and intelligently exploit some unique facilities.

Dr. Currie then stated the rationale for personnel cuts:

[illegible]t some laboratories do some outstanding work [illegible] are fully manned does not mean that there is no [illegible] improvement in their performance or that it [illegible] possible to operate with a somewhat smaller [illegible] he could maintain the present laboratory [illegible] with fewer people if the best qualified [illegible] would be retained despite age or seniority. This [illegible] under current Civil Service reduction- [illegible] regulations. Any reductions will inevitably [illegible]tive, at least in the short-term, because [illegible] more productive personnel lacking veterans [illegible] or seniority, will be forced out. If a [illegible] necessary, effective ways to offset these [illegible]fects must be found.

The argument, though not entirely clear, seems to be that if we could get rid of deadwood with age and seniority, then we could perform the same job more efficiently. One could argue, with equal justice, that considerably more money could be saved (hardware being always more expensive by orders of magnitude) if we insisted that industry live up to their contracts and that no cost overruns be allowed, or that we request industry to eliminate overhead costs (which include industrial deadwood). Or we could argue that universities should not allow inexperienced graduate students to work on government contracts so that we can get increased efficiency. Every organization includes more and less efficient workers, and if these are not properly utilized then we need better managers. Furthermore, personnel and program cuts do not necessarily give any indication of whether better or worse performers are being let go - they normally reflect judgments and prejudices of staff as to programs and people, and their current estimates of what is glamorous to the higher echelons. There are examples of programs which have been slated for abolition one month and which were high priority the following month because a system problem of importance was recognized in the interim. There are also examples of highly productive people, as judged by both quality and quantity of publications in the open literature and by their standing in the scientific community, who have been let go because their programs were not judged to be appropriately relevant. Age or seniority do not necessarily

mean senility, nor does youth necessarily mean innovation or imagination. If this were indeed the case we would insist that all generals be under the age of thirty and that every few years they be reduced in grade until they are finally privates. Clearly the criteria and the rationale for re-organizations, especially those affecting thousands of people, need to be more clearly stated so that a proper critical review can be made.

The In-House/Contract ratio: Is it related to systems support?

In the course of the Air Force Laboratory Utilization Study a questionnaire was distributed to the systems users asking which laboratories had contributed technical support for their systems. The percentages of in-house work at the six laboratories leading the list are the following: 58, 52, 31, 50, 71, 33. Thus the range of in-house work is from 31 to 71%. The mean for the six is 49%. All are above the 30% which is proposed as a desirable ratio. The question was also raised as to whether these laboratories would have been used if there had been a cost attached. The answer was a definite yes. Our conclusion must then be that utility of the laboratories bears no relationship to the in-house/contract ratio.

Distribution of high grade positions among the laboratories.

The Laboratory Utilization Study notes that there are 335 positions of GS-15 and above in the laboratories included in the

study, and that of these some 92 are at AFCRL. This figure, taken by itself, would seem to indicate an excessive number of high grade positions at AFCRL, since CRL has about 1000 of the roughly 11000 laboratory personnel.

Consideration of the context of these figures, however, shows that the conclusion is misleading and incorrect. Since the laboratories were set up for different missions the mix of high grade scientific talent, technicians, and support personnel will be quite different for each laboratory. We would not then expect, for example, that a laboratory devoted to testing equipment by routine procedures, if one were to be set up, and consisting entirely of technicians and support personnel, would have a very large number of high grades. On the other hand, a laboratory devoted entirely to the development of new knowledge and requiring highly trained, imaginative and innovative personnel, might be expected to have a higher proportion of high grades. I have tried to get some idea of the effect of some of these factors by calculating the percentage of high grades in terms of total number of civilians, number of science and engineering personnel, and number of Ph.D.'s, as well as the fraction of officers to science and engineering personnel. The results are given in the attached table.

CRL ranks fourth with regard to total civilians, and third with regard to science and engineering positions. With the

abolition of ARL these rankings would have to be moved up by one. The ratio of officers to S&E is lowest for CRL of any laboratory. Since officers are included in the S&E figure, the CRL percentage of S&E could be significantly lowered relative to other laboratories if only civilian S&E were included in the calculation, but I do not have these figures. The largest percentage of high grades by any of these measures is at AFOSR.

Perhaps the most revealing measure, however, is obtained when we calculate the percentage of high grades relative to the number of Ph.D.'s. This brings a considerable order into our scattered figures. For six of the eleven laboratories this percentage is between 50 and 55. This seems to indicate that at some time in the past, when scientific and technical competence (as opposed to relevancy) were the primary criteria, the number of high grades at an installation was determined by the number of most highly trained people, as measured by the number of Ph.D.'s. While it is true that competence and possession of the Ph.D. are not automatically equivalent (and at CRL, for example, many non-Ph.D.'s occupy high grades) it is nevertheless also true that possession of the Ph.D. demonstrates a certain proven level of ability, and that the presence of a significant number of Ph.D.'s at an installation should tend to upgrade the scientific and technical standards of the work done. By this measure, percentage

of Ph.D.'s, CRL is in this average group of six. The three laboratories below 50% have much higher percentages of Air Force officers than is typical for the laboratories. It seems likely that two of these, AFHRL and AFRPL, would come within the range if civilians only were considered. The third, AFWL, is largely military, and one would have to look at its structure in more detail before reaching any conclusions. Two laboratories have much higher percentages. The ratio for AFOSR is close to 90%, and if we consider that this laboratory also has the highest percentage of Air Force officers, it seems likely that every Ph.D. at OSR is GS-15 or above. The other high percentage, RADC, is almost three times greater than the typical middle group. For RADC, clearly, some other criterion must have been used to justify the high grades.

To summarize: If we take absolute numbers alone then CRL stands out in the number of high grade positions. If we take scientific and technical competence, as measured by the number of Ph.D.'s, then CRL is simply typical of the laboratories, OSR and RADC are over-represented, and AFWL is possibly under-represented. If an adjustment were made for military doctorates then it is quite possible that CRL would end up on the low side of the scale. In considering performance measures it might also be of interest to include such measures as publications in professionally recognized and refereed journals, or criteria such

as number of fellowships in the American Physical Society. The Laboratory Utilization Study and the Allen report do not seem to have used any criteria other than unsupported impressions. Scientific and technical competence seems clearly not to have been a criterion.

High-grade Positions in Air Force Laboratories

(GS-15 and above)

Laboratory	Number	Percent of Total Civilians	Percent of S&E	Percent of Ph.D.'s	Officer/Civilian Ratio
AFOSR	23	23.0	79.3	88.5	.792
ARL	31	17.8	43.7	51.7	.426
AFHRL	12	4.74	12.5	29.3	.342
AFAPL	15	4.29	7.94	52.2	.178
AFML	35	10.5	14.77	52.2	.167
AFRPL	7	2.44	7.22	33.3	.488
AFAL	25	2.84	5.57	50.0	.268
AFFDL	32	3.54	6.21	55.2	.215
AFCRL	92	10.2	17.0	53.8	.099
AFWL	7	1.74	3.29	5.34	.715
RADC	31	2.68	5.89	140.9	.240

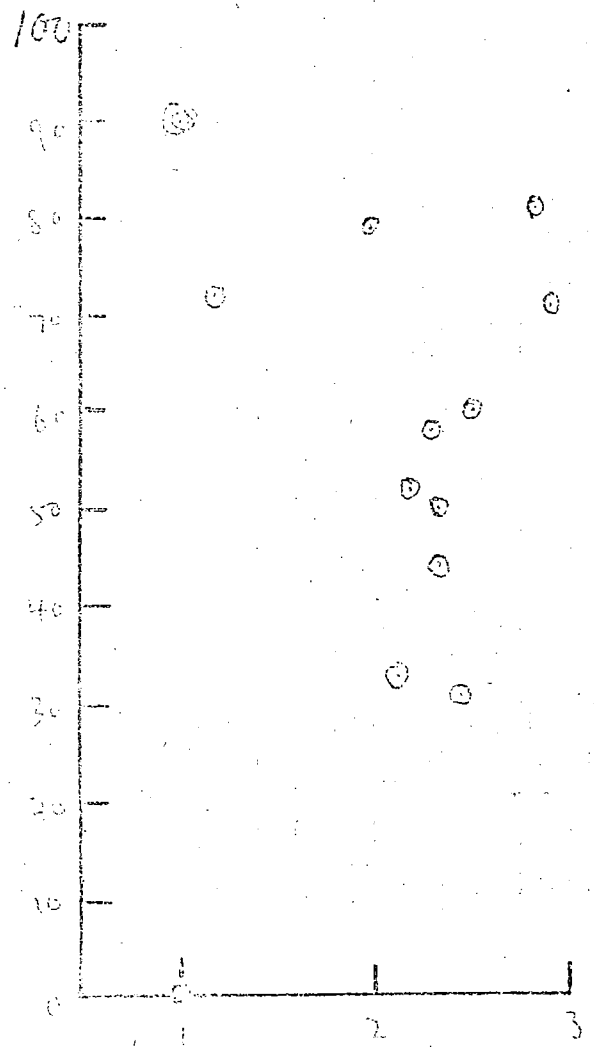
The in-house/contract ratio: is it related to the degree of application?

Since the focus of DoD research since the Mansfield amendment in 1969 has been on the relevancy of research, and thus on

the degree of application of the research, it seems worthwhile to inquire as to whether the in-house/contract ratio is related to this. We might, a priori, expect such a relationship in view of the finding reported in the Commission on Government Procurement of ratios of the order of 35% for basic and applied research and of 18% for development work. This trend is reasonable in view of the absence of governmental manufacturing facilities and the consequent dependence on industry for such services.

In order to test for such a relationship I have devised the following application index: The percentage of the sum of the funding for each of the categories 6.1, 6.2, 6.3, 6.4 and 6.5 is first calculated. These percentages are then multiplied by 1 for the 6.1 percentage, 2 for the 6.2 percentage, etc. Finally, the resulting products are summed and this result is the application index. If a laboratory is doing only basic research the index will be 1.0, if only exploratory development, 2.0, etc. The higher the value the higher the degree of application. The results may then be compared with the percentage of total funding which is in-house. In the attached figure this is shown for the Air Force laboratories, excluding the Seiler Laboratory at the Air Force Academy. Of the two which are wholly basic research, one, ARL, is 90% in-house, the other, OSR, is wholly contract granting. Almost all the other laboratories may be classed as development laboratories. The remaining laboratory, CRL, is

Application Index vs % in-house work -



primarily basic research (in the post-Mansfield amendment sense of the term). The in-house percentage for CRL is close to or less than three of the development laboratories. The range for the development laboratories is from about 30 to 80%. Thus if we leave out OSR, the trend is consistent with greater in-house percentages for basic research as opposed to development, but the range for development laboratories is greater than the difference between the research and development laboratories. It is likely, then, that a correct interpretation would involve the lesser need for manufacturing facilities involved in research, and that the percentage of funding used for in-house use will depend more on the mission the laboratory performs than on other factors.

The in-house/contract ratio: discussion.

It has been argued that the increased proportion of research funding going into salaries has led to a deprivation of funds for other sources, particularly industry and the universities. The solution proposed is the application of a rule of 30% of funds for in-house activities. The arguments leave much to be desired from the point of view of logic or even from a consideration of all the facts, as opposed to the narrow selection necessary to support this point of view.

Let us consider some of these points one by one. It has been noted that in the past ten years the proportion of 6.1 funds going for salaries has increased from 26% to 50% of the program element funding, and that this proportion for 6.2 has gone from 22% to 47%. No equivalent information is given for 6.3, 6.4, 6.5, or other procurement categories. It seems unlikely that industrial costs, which must be tied to inflation, have risen less steeply than government salaries. The reason for the greater proportion of funding in salaries is that research funding has not increased so that inflationary increases have not been taken account of. A transfer of funding from government to industry will not necessarily alleviate inflationary pressures, and, in fact, is likely to make the situation worse because industrial salaries are more likely to go up more quickly with inflation, and because the experience and objectivity of government scientists will be lost. There seems to be no equivalent proposal or outcry to convert industrial research to governmental salaries. Nor has there been any comparison of industrial inflationary cost increments (including overruns) with governmental costs to see which would be more cost effective. Clearly, some such studies should be made and placed in evidence before the DoD laboratory structure is destroyed.

It is argued that industry and the universities are losing their share of funding. Just let us see where the outside

funding actually goes. For DoD as a whole the percentage of all RDT&E funds which is in-house has been less than 30% for the past few years. For FY 74 and 75 this was 29%. The industrial share was 66%, universities about 2.5%, and Federal contract research centers also about 2.5%. For FY 76 and 77 these are scheduled to change to about 25% in-house, 71% industrial and about 2% each for universities and FCRC's. Thus the net result of the changes proposed (if we ignore for the moment the focus on research and look at the overall picture) is a transfer of 5% of the entire RDT&E budget, or something over $500 million, from in-house to industry, with the proportionate share of universities and FCRC's declining as well. The picture at the Air Force laboratories is not significantly different. Air Force funding for seventeen laboratories gave an in-house percentage of 28.6, with the remaining funding going primarily to industrial R&D organizations. The breakdown of the contractual effort is as follows: U.S. industry, 82%; U.S. educational institutions, 11%; U.S. non-profit institutions, 4%; other Federal agencies, 2%; and foreign performers, 0.2%. By emphasizing and focussing only on 6.1, or research, funding, which represents about 3% of the RDT&E budget, and ignoring everything else, it is proposed to alter the above balance by providing a 30% in-house ratio (when the overall ratio is already less than this for the

laboratories taken together), and to increase outside funding (which means to increase industrial funding since the overall funding for universities is slated to decrease). Already one of the two basic research laboratories has been abolished (on July 1, 1975) and the other laboratory with a basic research component is scheduled to be reduced to 60% of its size on July 1, 1976. Finally let us note that the Air Force already spends more, as a ratio of internal costs, on outside institutions than other laboratory systems. The ratio of outside costs to internal is, for: Air Force, 3.5; NASA, 2.0; Army, 1.0; Navy, 0.5; and Atomic Energy Commission, 0.2.

An important question in this discussion is whether the in-house/contract ratio needs to be, or should be, the same for all components in a laboratory system. I have noted earlier the wide range in this ratio and hypothesized that it probably varies with the mission. If this is the case there seems no reason to argue that every component should have the same ratio. On the contrary, if, for example, OSR is a granting agency then we would expect a very low ratio for this agency. On the other hand, if the mission of a laboratory involves areas for which industry or the universities do not have the capability or are not suited then we would expect the ratio to be high. Current plans argue for reducing the ratio of those laboratories which are higher

than 30% but do not at the same time envisage increasing the ratio for a laboratory below this. Why, for example, were not ARL and OSR combined, so that both achieved some balance, rather than abolishing ARL and increasing OSR's budget? Furthermore, why is CRL being dismantled on this basis, but the development laboratories, which all have a greater than 30% in-house percentage, and for which the same disproportionate increase in the salary fraction of funding exists, why is nothing being done to them?

The shift in funding from in-house to industry has not gone entirely unnoticed by the financial community. The New York Times for November 15, 1975, in the Market Place column, cites a securities analyst who is optimistic over the prospects for the aerospace industry in the coming year, and who "looks for expenditures of $18 billion for aircraft and missiles in the 1976 Federal budget, up from $15 billion in Fiscal 1975. His figures include expected expenditures for research and development as well as for the military and the National Aeronautics and Space Administration". Note the inclusion of research and development in the expected increases.

Cost effectiveness in DoD.

The net effect of changes in the RDT&E budget between Fiscal Years 75 and 77 is the transfer of 5.7% of the budget from

in-house, university and FCRC funding (but primarily from in-house) to industrial funding. In dollar terms this amounts to almost $1.2 billion for the two fiscal years 76 and 77 (including the transition year). We may then ask whether we may anticipate that this change will be cost effective. One way of looking at this is to compare an index of compensation for both private and civil service sectors. These are compared in Secretary Schlesinger's testimony, February, 1975, to the House Appropriations Committee (Hearings, Part 1, p. 44). The figure given is attached here. If we compare the percentage change from 1968 to 1974 (the period used in the DoD Allen report) then the private compensation has changed by about 54%, the defense civil service pay by about 50%, so that a change to private industry will be more expensive if the same work is done with comparable talent. While the percentages are not too different we must remember that they are operating on large numbers, so that actual dollar values can be quite large. Also, we may notice that the DoD report gives a figure for civil service increases for the laboratories of 40% for this period. If both DoD figures are correct and do not simply reflect bookkeeping differences, then the additional cost of going to industry will be much higher. We may also note that over a longer period, such as 1950-1975, the change to industrial funding represents a much larger increase in the cost disparity.

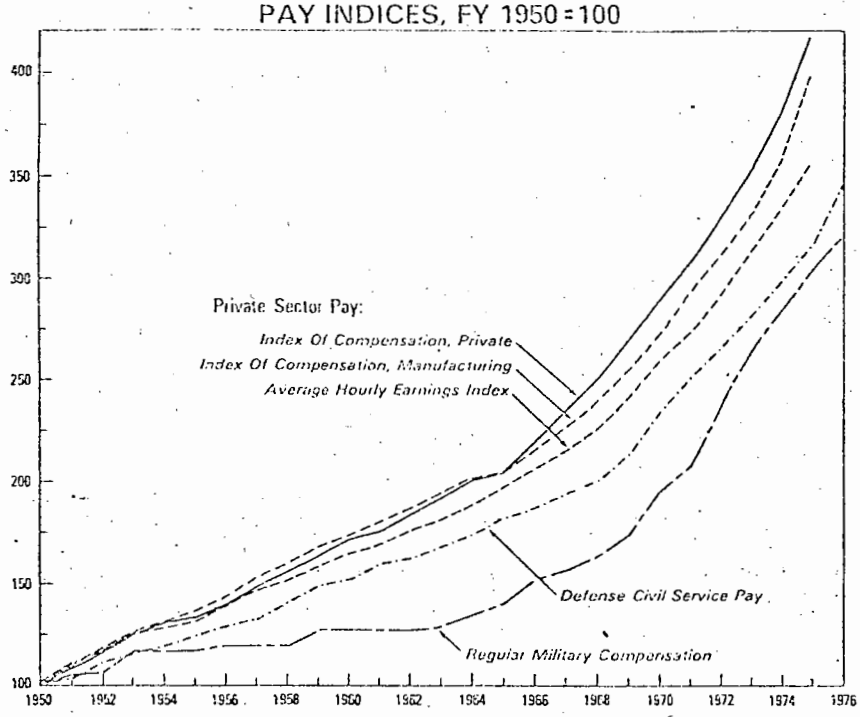
Another criterion used in the Allen report was to compare the in-house/contract ratio in 1968 with that in 1974 and to peg the proposed ratio to the earlier 1968 value. Testimony on the 1976 budget includes a figure on defense manpower from 1950 to 1976 (reproduced here. Taken from Hearings, Part 1, p. 534). This shows that the ratio of defense related employment in industry to defense civil service strength was roughly the same in 1974 as in, say, the late 1950's. The 1968 ratio is much greater, presumably due to the Vietnam situation. The year 1968, in fact, is the peak figure. Pegging the in-house/contract ratio to this base year is then pegging it to a wartime situation rather than the more normal peacetime situation.

Finally, we may ask what the inflationary effect on the cost of services might be. If we treat research as an industrial product to be contracted for then we use as a guide the known increase in the cost of DoD products. Some examples are given in the House hearings (Part 1, p. 528-529). These inflationary increases, for the one year from FY 75 to 76, range from 13% to 74%. Mr. McClary, Assistant Secretary of Defense, Comptroller, commented:

> A year ago in our 1975 budget, we estimated that the growth in these 3 years would be only 23 percent. We missed our estimate on the order of 13 or 14 points. Actually in our estimates we were fairly close on pay and where we missed our estimates, where we did not anticipate such great inflation, was in purchases. Actually on purchases we missed that by about 22 points.

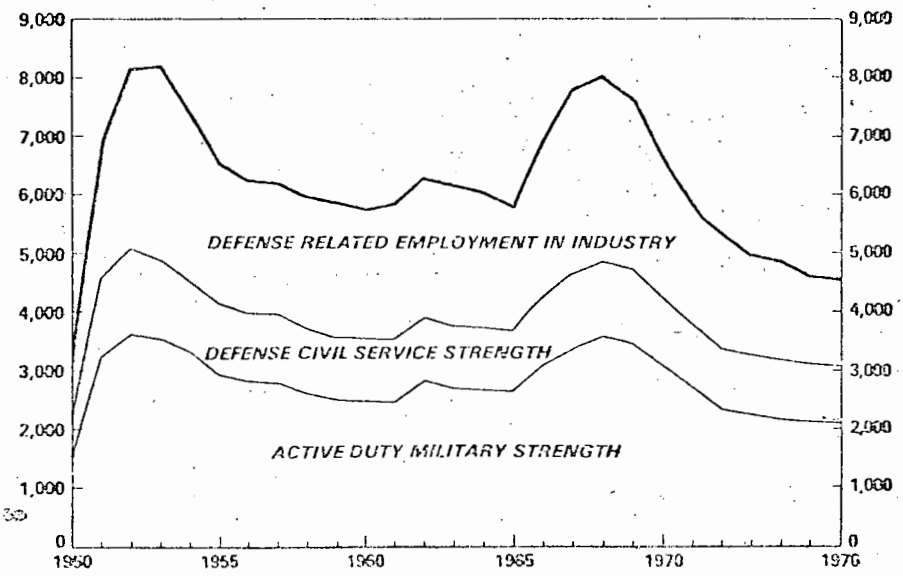
We may note that the estimates on pay was close but the cost of purchases was greatly underestimated. Civil service pay increases are being kept at a level considerably below inflationary increases, while industrial costs keep pace with inflation. Hence the transfer of funding from in-house to industrial is almost certain to result in less "product" or in much higher costs over the next few years.

PAY INDICES, FY 1950 = 100



DEFENSE MANPOWER

(THOUSANDS, JUNE 30)



The DoD and research: what is being done.

I have noted earlier that the net result of the changes made in the RDT&E budget between FY 75 and 77 is the transfer of 5.7% of the funding to industry, this amount being taken primarily from in-house funding, but also from universities and FCRC's. The proportionate share of the budget declines from about 15-20% for in-house and universities, and about 10% for FCRC's. Using the percentage change for each Fiscal Year period we can calculate the total monies transferred to industry. This amounts to (to the nearest million): $419 million for FY 76; $137 million for FY 7T; and $629 million for FY 77, the total for the two and one-fourth years being $1184 million.

The research share of the RDT&E budget declines by almost 13% over the two years. If we average the FY 74 and 75 percentages and compare these with the FY 77 percentage, then we obtain the following percentage changes over this period: Army, -12.96%; Navy, -12.21%; and Air Force, -12.90%. The likelihood of these numbers being so similar if each budget were drawn up independently would seem to be extremely small. The implication is that a ceiling on the research share has been set either at the Secretary of Defense level or by the Office of Management and Budget. It should be possible to distinguish between these two possibilities by consideration of other departmental budgets. If the

same philosophy and trends are evident there then it would be likely to be at the OMB level. In any event the resulting figures would require acceptance by each department.

Another way of dealing with the data to bring out what is happening is to calculate the percentage change for each type of performer as one goes from one fiscal period to the next. In the attached table these changes are shown. For the 74-75 period industry, in-house and FCRC show increases which are more less inflationary increases and roughly comparable to each other. The universities show a decline, which taking account of inflation, is a decline of the order of perhaps 7 or 8%. The major transition to the new distribution of funding occurs from FY 75 to 76. The industrial funding increase by over 26%. The in-house share, while it is less than the inflationary increase, is not yet drastically cut. The universities receive a large increase here and an equal increase for the transition period. The FCRC is of the order of 7% (approximately inflationary) over the period from 75 to 77. As we go from 76 to 77 the industrial increase, while remaining the largest of all the categories, is less than for 75-76. The in-house funding receives a large decrease when inflationary rates are taken into account, of the order of perhaps 7% or more. The universities are again reduced from 7T to 77, to an even greater extent than from 74-75. Thus overall industry gains by large amounts in all time periods. In-house research funding is cut to an extent that significant personnel cuts will

have to be taken to accommodate the cuts. The universities, after an initial period of boom, go bust again. Finally, if we remember that the percentage of FCRC funding decreases over this period, we see that it is not simply a re-distribution of funding which is involved, but that additional monies are also being added in for industrial funding.

Percentage Changes in Budget by Type of Performer

Fiscal Years	74-5	75-6	76-7T	7T-77	76-7
Industry	4.928	26.181	6.351	3.448	10.014
Govt. In-House	6.019	4.232	0.975	0.083	1.059
FCRC's	6.080	7.130	0.913	5.991	6.960
Universities	-0.749	5.684	5.664	-1.306	4.284

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THE FUTURE: WHAT IS TO BE DONE?

SUMMARY

It has been and is generally accepted that basic research is essential for the introduction of new systems over the long term. In the nineteenth century the growth of university research departments in Britain was a direct result of the demonstration of German superiority resulting from the support of basic research. In the past few years in the United States there has been a consensus among leaders in industry, government and the universities as to the necessity for support of research. Senator Mansfield, in arguing for the need for relevancy of Defense Department research, was not disputing the value of research itself, merely who should perform it.

Historically the performers of research in the U.S. have been government, industry, foundations, and consulting firms, including non-profit organizations. Each has had a particular sphere of interest: undirected, long term research suitable also for the training of graduate students for the universities; applied research needed for the solution of very specific problems and kept out of the public domain so that proprietary rights can be protected, for industry; the collection of basic data and the filling in gaps in our knowledge where required for recognized national needs and policy decisions, for government; social programs in areas not otherwise supported, for the foundations, and consultations on specific problems of an operational nature, for the consulting firms. Government laboratories

have typically operated with a mix of in-house and contractual research, the proportions being considerably different for different bureaus. Some bureaus, such as the National Science Foundation, were specifically set up to provide grant support and to do no in-house work themselves. Others, such as the Agricultural Experiment Stations, were set up as primarily in-house laboratories, even though they may have operated through the State universities. Typically where a bureau has no in-house work reliance is placed on outside review panels for judging proposals. Problem oriented bureaus with in-house research typically use contractual support chosen to complement the in-house part of the program. Government support of research is indicated when tangible, recognized national needs are present and when private means are insufficient to develop solutions for these needs.

It is important also to recognize that a given national need has a life cycle. In the early phases the development of new knowledge needed to conceptualize and develop approaches is perhaps the least expensive part of the cycle. Development of hardware, demonstration projects, etc., are the next stage and considerably more costly. Finally, the stage of widespread use and diminishing returns on investment occurs. This is also the stage presenting the most difficulties in terms of the bureau

having outlived its usefulness but still maintaining a large and well entrenched bureaucracy. Few bureaus, the Steamboat Inspection Service being one perhaps, know how to die gracefully. Some adapt to new needs, others develop a service function.

I propose the formation of a laboratory of national needs which will take account of real needs and the real problems of aging bureaus. One function of the laboratory will be the recognition of upcoming needs, that is, the forecasting of coming crises in order that action can be taken to prevent the crisis from occurring. The energy crisis could easily be, and was, foreseen by consideration of the exponential growth in the use of energy and the lesser growth of energy sources. In the past few years inflation has begun also to show an exponential dependence, and the consequences can easily be seen as a massive disruption of the processes of our society's operation. Non-renewable resources, metals, wood, are again good examples of coming crises. The proliferation of sophisticated weaponry and their spread among many states throughout the world are very clear danger signals. Thus the development of, proof, and use of techniques for crisis forecasting is an important function.

For a laboratory devoted to national needs, new knowledge is not enough. It is important that this knowledge be made available in appropriate forms to those whose job is the solution

of the problems inherent in the national needs. It is known that the gap between new knowledge and the application thereof can be of the order of decades. It is important to reduce this time lag. Interfacing theory, that is the methodology of providing an interface between theory and practice, needs to be a part of this laboratory. In its most naive form this is considered to be the province of management. Considerably more needs to be done, including new conceptualizations of the problems inherent in interfacing.

The organization of such a laboratory needs to be considered carefully. The first problem is the allocation of resources. I would suggest that 3% of the Federal budget be set aside for this purpose. Some fraction (perhaps 10%) of this should be set aside for new, urgent problems and for undirected research by proven achievers. The remainder could be allocated to each government department (Defense, Justice, etc.) proportionately to their share of the Federal budget, which is taken here as a measure of national need requirements. In order, however, to insure that the departments have bona fide requirements, it can be required that the moneys are available only if matched by at least an equal amount by the individual department. Liaison people, whose function will be interfacing the new knowledge with departmental requirements, and feeding these requirements back to the researchers,

will be needed. In order to avoid ossification of research projects funding can be for limited times, such as five years, with perhaps only one renewal allowed. The project manager could, however, be free to develop funding from any department in government. All project managers could be required to sit in on conferences in which the different departments needs are presented to allow for both cross-fertilization and for the stimulation of new projects. Proven achievers could be allowed one assistant and some minimal funding for equipment without the need for satisfying departmental need requirements. With some such organization or a modification thereof it should be possible to set up a laboratory responsive to current national needs and which would be constantly changing as these needs change.

ABSTRACT

Federal Support of Science and Technology

by

S.M. Silverman

January 1976

This paper addresses recent USAF actions with regard to its in-house laboratories which will decrease USAF support for basic research which would be conducted in-house and increase support for such research to be conducted by industry. The impacts and implications of this course of action are discussed and the wisdom of following such a course of action is questioned.

The introductory pages provide some historical perspectives of Federal government involvement with and support of research activities, with particular emphasis on illustrations which show that basic research with its objective of increasing knowledge is among the first items to be cut during times of 'tight' budgets. Those applied research efforts, those from which tangible practical results are expected have received priority, in spite of the general acceptance that basic research is essential for the introduction of new systems over the long term.

Additional background information is provided which treats the issue of the organizations in which research is performed, with examples which show that the research function must be separate from the production or operating function. Vannevar Bush is quoted as saying, "Industry learned a long time ago that it was fatal to place a research organization under a production department."

An analysis is provided which indicates that an appropriate level of support for R&D is of the order of 4% of the total budget or sales for relatively non-competitive situations, perhaps doubling to 8% as competitiveness increases. The fraction of this which should go to basic research will depend on the novelty of the problem and the need for innovation and imaginativeness. However, the personnel cuts due to the recent USAF action may be estimated as something like 285 out of 650, or over 40% of those involved in basic research.

Part II of the paper, "The Defense Department and Research" provides detailed information on what is actually taking place concerning DOD support of basic research efforts. Information from the DOD appropriations hearings for FY-76 shows that about

3% of the RDT&E funds are allocated to what might be termed basic research, that is, the 6.1 category of funds. A breakdown of where USAF RDT&E funds are utilized for the years FY-74 through FY-77 as shown below, clearly illustrates that the primary result of the planned changes are the shift of about 5% of the RDT&E budget in-house laboratories to industry.

FISCAL YEAR	PERCENTAGES			
	IN-HOUSE	INDUSTRY	UNIVERSITY	FCRC
74	29.0	66.1	2.44	2.47
75	29.2	66.0	2.31	2.49
76	23.6	70.1	2.05	2.24
77	24.1	71.7	1.99	2.23

Possible rationale's for this shift are discussed but none are found other than a policy determination to shift resources from in-house efforts to industry apparently without regard for the cost-effectiveness of such a change. In the discussion which attacks the application of a rule of 30% of funds for in-house activities it is pointed out that this ratio most likely should not be the same for all of the laboratories and that the ratio of in-house to out-house expenditures should be a strong function of the roles and missions of the individual laboratory organizations.

It can also be seen that the percentage of the resources available for work in the universities and in the Federal Contract Research Centers is also decreasing or remaining relatively constant. The analysis shows that the transfer of funding from in-house to industrial organizations is almost certain to result in less "product" or in much higher costs over the next few years.

Part III, "The Future: What is to be Done" provides a general summary and proposes the formation of a "laboratory of national needs", which will take account of real needs of the Nation and the real problems of aging Bureaus. One of the primary functions of such a laboratory would be the prediction and identification of future needs and problems and to initiate action to prevent these needs and problems from becoming crises. It is pointed out that the outputs of the laboratory must be in a form appropriate for use by decision-makers.

Roberts of ERDA sees need for breeder reactor

Dwindling US uranium reserves may force Americans to supplement conventional energy sources with the breeder reactor by the end of this century, according to ERDA's Richard W. Roberts. Roberts, the agency's Assistant Administrator for Nuclear Energy since 30 June 1975, is confident that the pace of the US breeder program matches the country's needs. (The Clinch River Breeder Reactor, a 350–400-MW prototype, is scheduled to become critical in the late fall of 1983.) He acknowledges, however, that some foreign competitors have surpassed the US in breeder development.

Concern for safety, Roberts told us, has played a substantial role in the history of conventional nuclear reactors. As for the breeder reactor, "I believe it will be an extremely safe system," he said. He also commented on the use of nuclear energy in space exploration and roles for physicists in nuclear energy.

Roberts, who holds a PhD in physical chemistry from Brown University, is responsible for the development of nuclear power systems. Programs under his direction include the continued development of conventional reactors and of special reactors and generators for the Navy and space vehicles, R&D on the Liquid Metal Fast Breeder Reactor, the provision of nuclear fuel material and R&D on the nuclear fuel cycle. Roberts came to ERDA from the Department of Commerce, where he was Director of the National Bureau of Standards. Before that, he did research and held management positions at General Electric Co's R&D center in Schenectady.

Breeders for the future. The US may have to switch from conventional nuclear reactors to breeders (which produce more plutonium fuel than they consume) by the end of the century, Roberts told us, because at that time its resources of uranium could well be insufficient to meet the needs of additional reactors for their 40-year lifetime. "Right now," he said, "we can only utilize U^{235}, which occurs as about 0.7% of the ore mined. The breeder reactor promises to convert that other 99.3% that is U^{238} into plutonium and use it as fuel." According to Roberts, ERDA's three diffusion plants have stockpiled enough U^{238} hexafluoride of high purity to supply 500 1000-MW breeder reactors for 250 years.



ROBERTS

Need for the breeder becomes more evident when one notes that last year nuclear reactors supplied 9% of the

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Agencies reduce in-house R&D in favor of industry

Reductions in the in-house component of major Federally funded R&D programs appear to have resulted from Government policy decisions taken over the past three years. Federal spokesmen invoke various explanations to account for the cutback on in-house research: A Commerce Department official cites the Administration's preference for a limited Federal role as the essential consideration, while the Department of Defense ascribes its policy to specific aspects of the DOD's in-house operations.

Information that suggests the switch to increased private-sector research is Federal—not just DOD—policy is confirmed by agency officials we consulted. While in absolute terms Federal support increased in terms of current dollars for both industrial and in-house R&D over the FY 1975–77 period, according to National Science Foundation figures the *relative* share for industry out of the total increased by 4.3%.

In-house R&D fraction diminishes. The trend in relative support for in-house activities has been downward at DOD and within the Federal R&D program as a whole, though NASA and ERDA show modest gains in this area as well as in the industrial sector (see table). The two agencies and DOD account for over 90% of Federal expenditures for R&D in industry. Earlier figures cited by Sam Silverman in a study on Federal support for science and technology reveal the same movement away from in-house activities. Silverman, a former employee at one of the DOD in-house labs (Air Force Cambridge Research Laboratories, Bedford, Mass.) contends that there exists "... a broader trend [than at DOD] toward more industrial funding, though this is not consistent from one department to another."

We asked Michael I. Yarymovych, Assistant Administrator for Field Operations at ERDA, about the applicability to his agency's in-house program of a policy shift. Yarymovych, who is responsible for ERDA's field structure and the agency's relations with the national laboratories, told us the data are accurate and "... the points [Silverman] makes concerning trends in funding patterns ... are valid." Similar confirmation came from a NASA spokesman, though he added that it will be some time before the policy shift there becomes evident from the budget numbers.

It is Defense Department policy, according to statements by Malcolm Currie, Director of Defense Research and Engineering, and his deputy, John L. Allen, to increase the private sector's share of R&D work at the expense of the in-house effort. Currie set a 30% funding limit on the in-house component of the Technology Base program for FY 1977 (see PHYSICS TODAY, November 1975, page 104), and a laboratory-utilization study directed by Allen recommended that "manning of the Physical Science and Engineering laboratories should by reduced by 10–15% from the FY 1974 end strength." Their recommendation is expected to result in a staff reduction of about 10% by FY 1978.

Why the change? Betsy Ancker-Johnson, Assistant Secretary of Commerce for Science and Technology, verified the in-

Percentage shares of in-house and industry funding in the Federal R&D budget*

	FY 1975	FY 1976	FY 1977 (est.)
Government-wide			
In-house	28.3	27.4	25.8
Industry	44.0	45.9	48.3
NASA			
In-house	34.0	34.3	34.2
Industry	58.5	59.3	59.7
ERDA			
In-house	3.2	3.9	3.8
Industry	24.2	33.8	36.3
DOD			
In-house	30.7	29.7	27.3
Industry	62.2	63.8	66.5

*From NSF 75-334, "Federal Funds for Research, Development and Other Scientific Activities, FY 1975–77."

creased stress on private-sector research in her Department with the explanation that "it is very much a goal of this Administration to avoid doing anything in the Federal Government that can be done privately." For example, she told us, a considerable investigation has gone on to check that the National Bureau of Standards performs no tasks that ought to be done, or could be done, elsewhere. (It doesn't, according to Ancker-Johnson; she said NBS passed the test "extremely well.")

The rationale behind DOD's shift away from the in-house labs appears more complicated. On the one hand, Allen's study has noted that the Congress "has made clear its intention that DOD R&D has no mission to support science or scientific training" beyond the Department's own needs. This conclusion may stem from the 1970 "Mansfield amendment," which provided that no funds authorized for Defense use by the Congress could be applied to projects or studies not directly related to "a specific military function or operation." (The NSF absorbed much of DOD's less obviously defense-related basic research.) In apparent contrast to this restricted-role justification, however, Allen has said that the desire to increase technology transfer within the United States was one of the factors underlying the move to reverse the growth of the in-house share of research efforts: "To get high technology into industry rapidly," he said recently, "one just about has to develop the technology there in the first place."

Other considerations cited in the development of the Pentagon's present approach include the following:

- disproportionate growth in the in-house operation over the 1964–74 period, which culminated in a 43% in-house share, averaged over the independent Army, Navy and Air Force programs, in 1974;
- a layered management structure in the in-house enterprise that contributed to inertia, inhibiting response to new challenges;
- assertions of better capability (in specific areas) in industry and the universities, alluded to by Currie, and
- the accretion of personnel who constituted advocacy groups for "matured constituencies," areas of research or technology—a solid-state research effort concerning polycrystalline graphite, for example—for which Defense policymakers believe the demand has waned.

—FCB

Stever is new White House science adviser

The Senate confirmed on 9 August the nomination of H. Guyford Stever to be Director of the new Office of Science and Technology Policy. Stever, Director of the National Science Foundation since February of 1972, had served as part-time *ex officio* adviser to the President on scientific affairs since the abolition of the White House science office in mid-1973. In moving up to his present fulltime role, he becomes the first White House science adviser to serve on a statutory basis.

Stever's primary duty as OSTP director is, of course, to advise the President on scientific, technological and engineering aspects of issues confronting the White House; the science-policy act signed into law by President Gerald R. Ford in May includes among such issues problems of the economy, of national security and foreign relations, of health and of the use of resources and the environment. The White House science adviser holds membership on the Domestic Council and is expected to advise the National Security Council. The new legislation requires that he join with the Office of Management and Budget in annually reviewing Federal funding of R&D. Stever will also assist in the preparation of a yearly report from the President to the Congress on science and technology. His office, which is to include not more than four associate directors nominated by the President and subject to Senate approval, must also identify problems of a scientific nature that may affect Government decisions in a five-year forecast to be updated annually.

Before he took charge of the Foundation, Stever had been president of Car-



STEVER

negie-Mellon University in Pittsburgh (and one of CMU's predecessors, Carnegie Institute of Technology) since 1965. Earlier he headed MIT's Departments of Mechanical Engineering, Naval Architecture, and Marine Engineering. He earned his PhD in physics in 1941 from the California Institute of Technology.

Stever's research interests have included aeronautical, missile and spacecraft engineering, design and performance (especially aerodynamics) and radiation physics. He has also been active in scientific and engineering education and the determination of science policy. His best known research work consists of studies on condensation phenomena in high-speed flows and the growth of the boundary layer behind a shockwave.

—FCB

Roberts

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country's demand for electricity. "Projections I've seen show the nuclear share increasing to about 25% by 1985," said Roberts, "and around the year 2000 they may supply as much as 50%." Yet the breeder can supply no significant amount of electricity, he predicts, until 1995 or beyond. As breeder technology matures, Roberts told us, utilities will probably shift over from the light-water reactors of

Is the transfer of funds to industry government-wide?

I have noted elsewhere that the primary consequence of the budgetary changes of the past two years in DoD is the transfer of funding from in-house to industry. The question then arises as to whether this is part of a government-wide trend or unique to DoD. Examination of the data indicates that there is in fact a broader trend towards more industrial funding, though this is not consistent from one department to another. In the accompanying Table I have calculated the in-house and industry shares of funding for the government as a whole and for the four departments with the largest budgets: DoD, NASA, ERDA, and HEW, representing 86.7% of the total R&D budget. For the government as a whole the increase in industrial percentage points, about 4, is almost the same as that for DoD. The increase for NASA is small, less than 1%. There are, however, indications from newspaper articles that it is intended to increase NASA's contract operations. ERDA has shown a large growth in the past two years, and this growth is matched by the growth in industrial funding, which has risen by almost 12 percentage points from its starting point of 18%. HEW has a small industrial share to begin with, and this decreases slightly. Thus overall, the industrial share is increased, though individual departments may differ radically from this behavior. The dollar value of the increase alone, using the FY74 and 75 average as a base, for FY76 is about $838 million.

Percentage shares of in-house and industry funding in the Federal R&D budget.

Source of Data: NSF 75-323

	Government-wide		DoD		NASA	
FY	in-house	industry	in-house	industry	in-house	industry
74	27.61	44.99	30.05	62.54	33.09	59.45
75	28.05	44.42	30.32	61.99	33.81	59.18
76	26.58	48.57	27.49	66.32	33.65	60.12
Δ74-6	-1.03	+3.58	-2.56	+3.78	+0.56	+0.67

	ERDA		HEW	
FY	in-house	industry	in-house	industry
74	2.01	17.72	17.54	6.21
75	3.00	22.66	19.41	6.26
76	3.12	29.44	20.64	5.95
Δ74-6	+1.11	+11.72	+3.10	-0.26

$^{\Delta}$74-6 = change from 1974 to 1976.

In order to have a proper perspective it is important to remember that the bulk of the R&D budget is concentrated in only a very few agencies. In the following table I have ranked the agencies in terms of the amount of funds they give to industry. I have included also each agencies percentage of the total and the cumulative percentage as we go down in rank, up to the point where the cumulative percentage goes above 99. We note that two thirds of the industrial funding comes from the DoD, the top three contribute more than 93% of the funding, and the top eight more than 99%. HEW, despite its low percentage of industrial participation, nevertheless ranks fifth as a funder of industry because of the large size of its budget.

We may obtain another measure of the shift to industrial funding in the following way. I have included in the table both the increase (except for HEW, which decreases) in the dollar value of industrial funding for each agency as well as the increase (except for Labor, which decreases) in the total R&D budget for each agency between FY74 and 76. From these I have calculated the percentage of the total budgetary increase going to the industry. For mental comparisons we may keep in mind the percentage of Federal funds going to industry in 1974, i.e., 45.0%. For DoD, NASA, and ERDA, the three top; funders of industry(93% of the total) the percentage of the total budget increases going to industry are 81%, 65%, and 49%, respectively. For the three taken together the figure is 71%. It is clear that industry is the major beneficiary of budgetary increases in FY76.

Industrial R&D Funding by Rank
Source of Data NSF 75-323

Rank (1976)	Agency	Fiscal Year 1974 Funding (millions of dollars)	Percent of Total	Cumulative Total (%)	Fiscal Year 1976 Funding (millions of dollars)	Percent of Total	Cumulative Total (%)
1	DoD	5266.1	67.13	67.13	7053.3	67.07	67.07
2	NASA	1784.9	22.75	89.88	2062.7	19.62	86.69
3	ERDA	263.9	3.36	93.24	701.5	6.67	93.36
4	DOT	204.7	2.61	95.85	209.7	1.99	95.35
5	HEW	142.3	1.81	97.66	138.5	1.32	96.67
6	EPA	60.9	0.78	98.44	124.0	1.18	97.85
7	Interior	28.5	0.36	98.80	88.1	0.84	98.69
8	Commerce	38.1	0.49	99.29	39.1	0.37	99.06
9	HUD	17.7			32.6		
10	NSF	14.7			23.2		
11	Nuclear Regulatory Comm.	3.1			21.7		
12	Justice	6.1			7.4		
13	Fed. Energy Adm.	--			3.4		
14	Labor	2.1			2.2		
15	GSA	1.0			1.9		
16	State	0.6			1.1		
17	ACDA	0.5			1.0		
18	Agriculture	0.8			0.9		
19	Office Telecomm. Policy	0.1			0.9		
20	Small Business Admin.	—			0.9		
21	FCC	0.2			0.8		
22	Library of Congress	--			0.4		
23	VA	0.3			0.3		
Total		7845.2			10515.5		

Rank (1976)	Change in total R&D budget 1974-6 (millions of dollars)	Change in industrial funding (millions of dollars)	Percent of increase going to industry
1	2214.9	1787.2	80.69
2	428.5	277.8	64.83
3	893.8	437.6	48.96
4	32.3	5.0	15.48
5	35.7	-3.8	-10.64
6	131.2	63.1	48.09
7	138.4	59.6	43.06
8	49.2	1.0	2.03
9	7.4	14.9	201.35
10	121.9	8.5	6.97
11	45.3	18.6	41.06
12	7.3	1.3	17.81
13	3.8	3.4	89.47
14	-0.3	0.1	—
15	0.2	0.9	450.0
16	13.2	0.5	3.79
17	0.6	0.5	83.33
18	84.4	0.1	0.12
19	1.1	0.8	72.73
20	1.1	0.9	81.82
21	0.7	0.6	85.71
22	3.1	0.4	12.90
23	13.0	0.0	0.0
total	4213.7	2670.3	63.37

Correlation coefficient = +0.929

$\sigma_{\log_B} = 0.7474$

$\sigma_I = 25.6448$

$r^2 = 0.8627$

This phenomenon is not confined simply to the largest agencies. If we average the nine agencies with increases in total budget of less than $10 million (leaving out Labor, with its decrease), then the fraction of total budget increase going to industry averages out to 122% (for some agencies, clearly, money has been transferred from existing programs to industry). If we leave out the two highest figures and one lowest figure to take account of extremes, the average percentage is 72%, comparable to the 71% for the top three.

An interesting aspect of the data is that, if we take only those agencies with total budget increases greater than $10 million, then most of the data can be fitted to a semi-logarithmic plot, as shown in the accompanying figure. Analytically, we are fitting most of the data to the equation

$$I = k_1 \log B + k_2$$

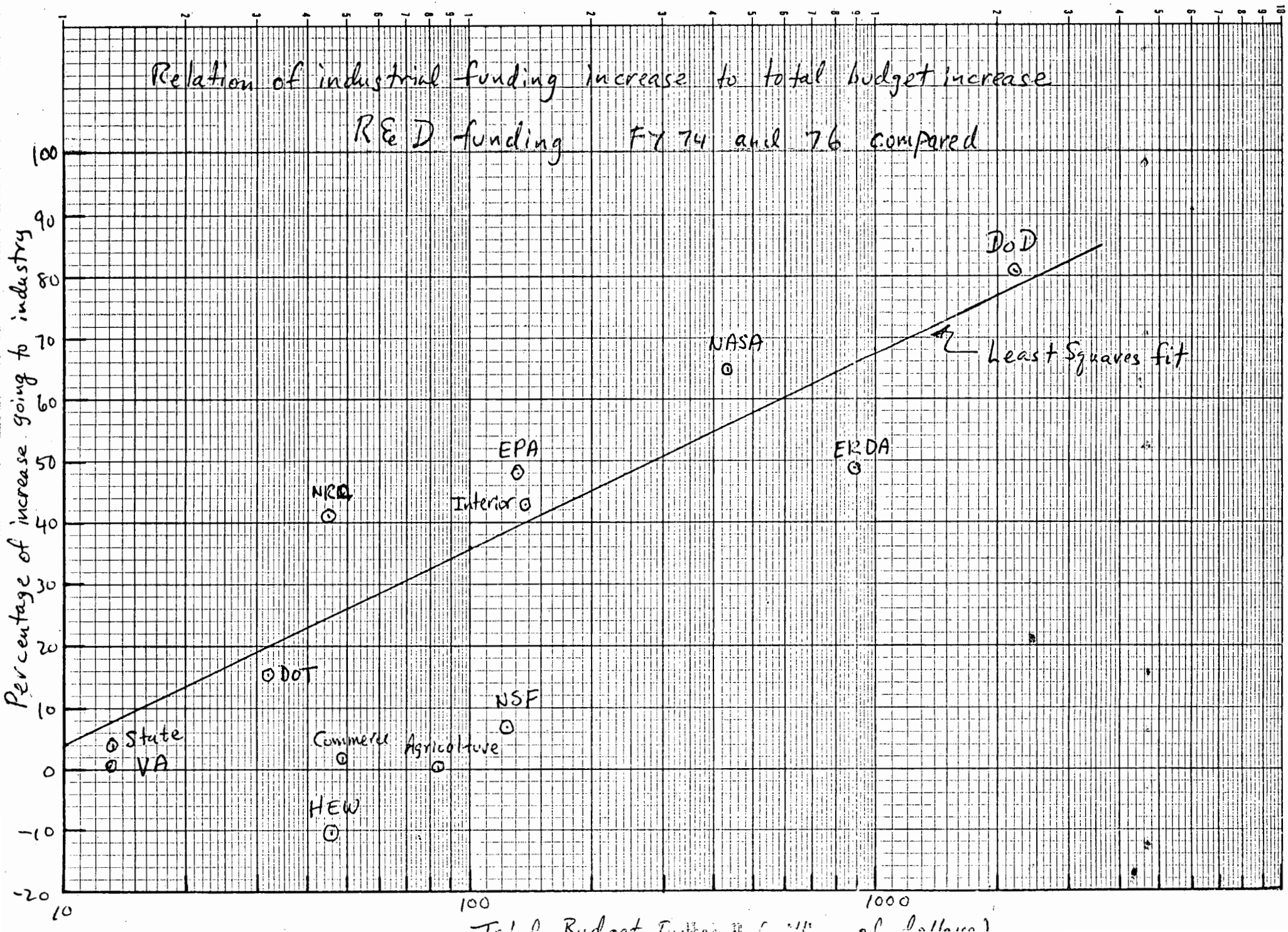
where B is the increase in the total budget, I is the percentage of that increase going to industry, and k_1 and k_2 are constants. The data, with the exception of NSF, Agriculture, Commerce, and HEW, were fitted by the method of least squares to a line of this functional form. The resulting equation is

$$I = 31.869 \log B - 27.378$$

The correlation coefficient for this data is 0.93, which is very high indeed. What the graph means is that the higher the increase in the budget, the greater will be the percentage going to industry.

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SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS AD-0837-6D

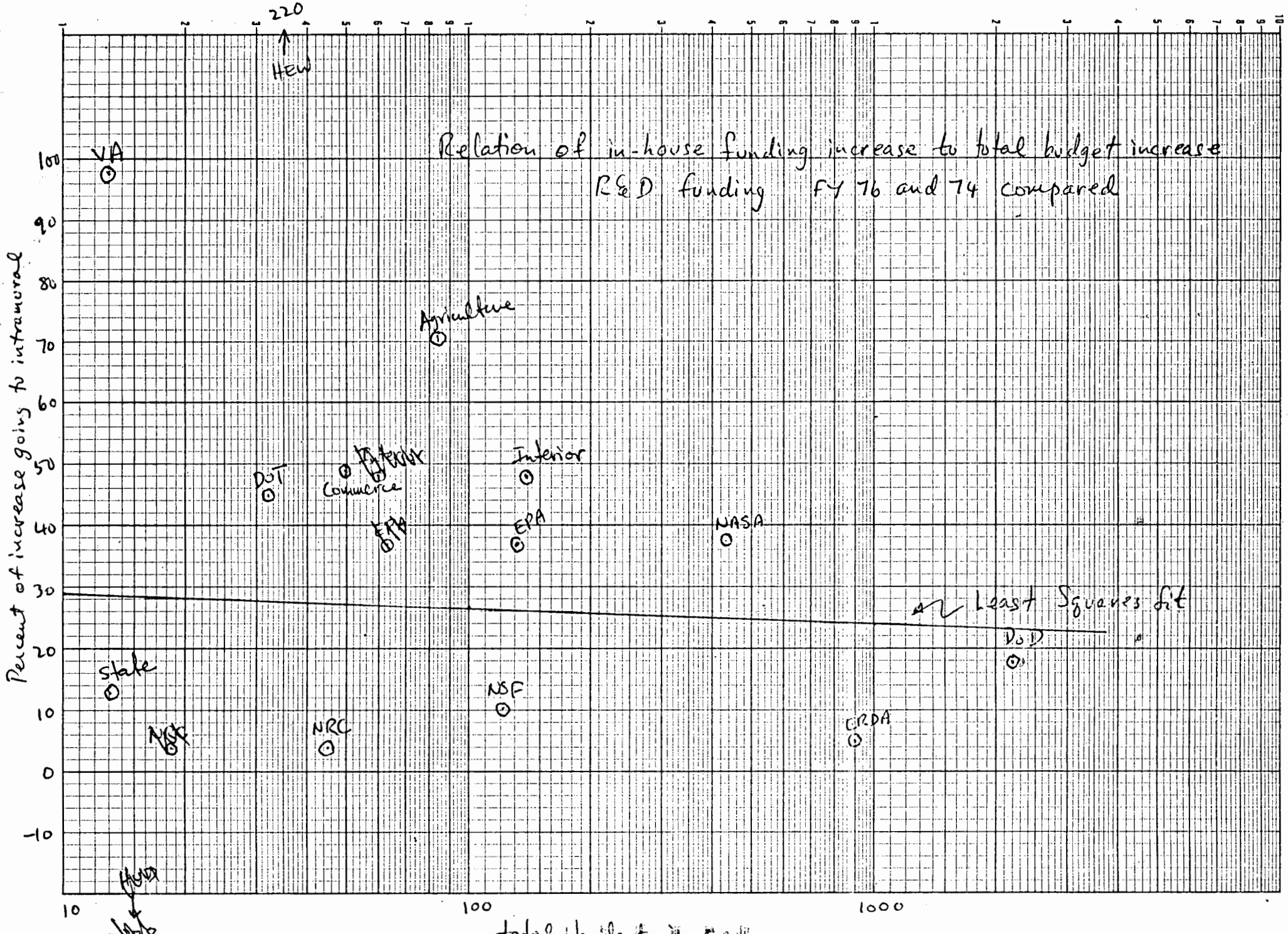


One way of deciding whether these results are a mathematical accident is to apply the same procedures to another parameter and see whether we get the same result. For DOD, funding is almost entirely either industrial or in-house. For other agencies other performers are important. If in-house were the only important performer for all agencies then we would expect the inverse behavior for the same type of plot. That is, since for industrial funding the percentage of budget increase going to industry increases with the size of the budget increase, then the remainder should decrease. If no constraints are placed on the budget then we would expect that there would be a random fluctuation about the mean for the different agencies. In the following graph I have plotted the percentage increase versus the total budget increase for the in-house portion of the funding. Though there is a slight negative slope, indicating that in-house is the major other performer, the result is basically no correlation. That is, there is in fact a random fluctuation about the mean. This indicates that no particular constraints have been placed on this portion of the budget, in contrast to the situation for the industrial portion of the budget.

A similar effect is evident when the university share of the increase is plotted against the total budget increase. While there appears to be a slight negative slope to the least squares line this is not statistically significant. Almost all of the university shares are below 20%. The one exception to the general rule is NSF, which historically was primarily set up for university funding. Here the majority of the additional funding goes to universities. NSF thus remains the showcase of Federal support of unversity research.

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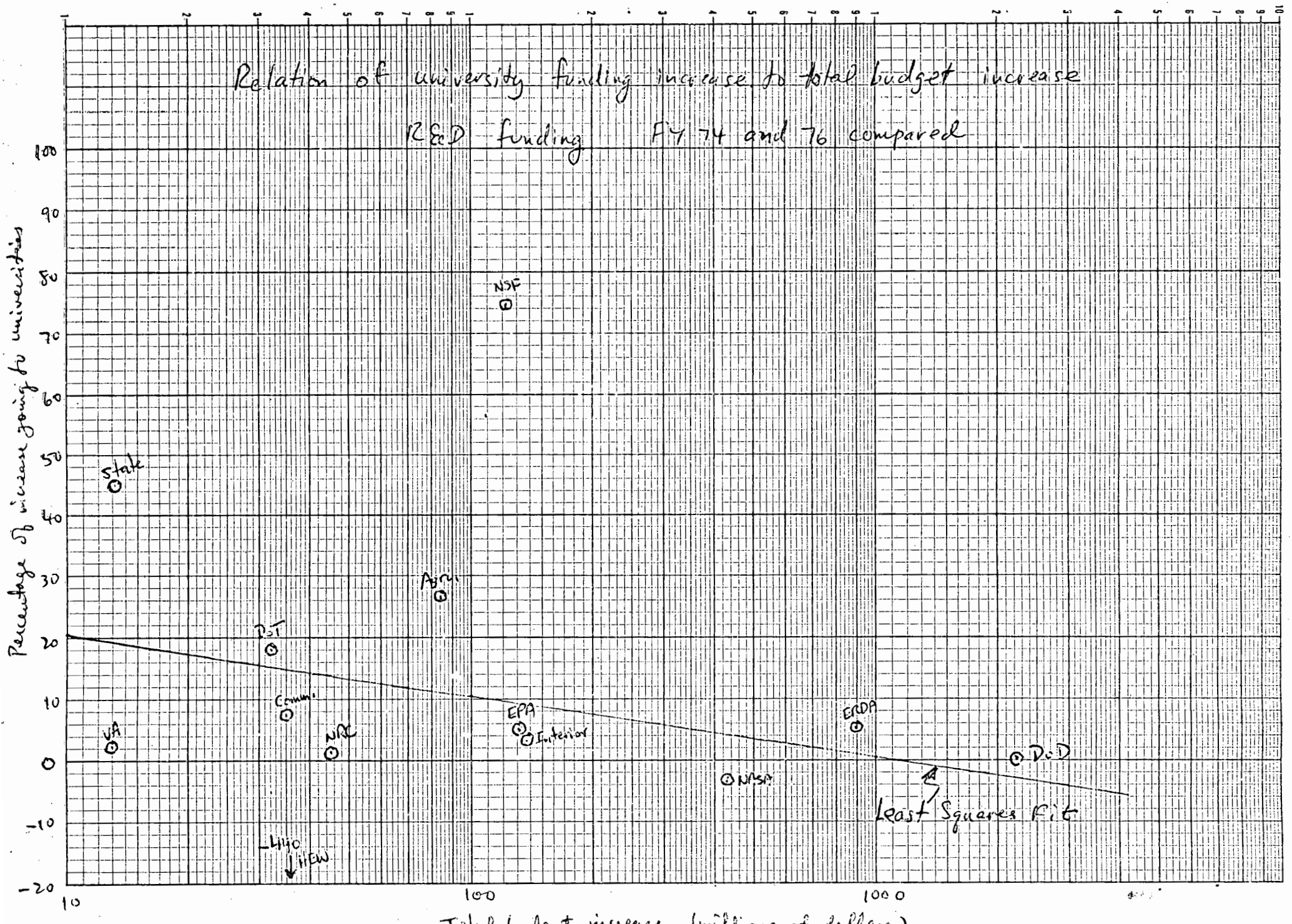


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Relation of university funding increase to total budget increase

R&D funding FY 74 and 76 compared



As a statistical footnote to the preceding discussion I have estimated the significance of the correlation coefficient relating the increased funding to the percentage of that funding going to industry. Application of the t-test gives a value of $t = 7.58$, for nine degrees of freedom, which is significant at much more than the 0.1% level, so that the correlation is highly significant. I have also calculated the z-transform, and, comparing the standard error of z with z on the assumption that the data are uncorrelated, we find the z to be almost 5 standard errors away. That is, the likelihood of the data being uncorrelated is less than one in a million. Finally, taking the standard error for the correlation coefficient itself, the value of the correlation coefficient if we were off by three standard errors would still be 0.80, or significant. These latter two tests must be treated with caution when dealing with small numbers. The overall result, however, seems clear, that it is most unlikely that the correlation found here has occurred by chance. Constraints have been imposed on the budget of the sort described here, and what remains is to determine where, by whom, and by what criteria these constraints have been applied.

It is interesting to speculate on the factors which leave several agencies much below the curve. ERDA, though a new agency, is the successor to AEC, which had a large network of existing contractual arrangements. I have noted in an earlier paragraph that the industrial share of ERDA budgets has been increasing sharply over the past two years. Here it seems likely that if this trend had started a year or two earlier this point would also have been nearer the curve. NSF was set up originally as sponsor for basic research, primarily in universities. The more recent RANN program allowed for greater industrial participation as well. NSF, however, provides grants using the peer review system, and the reviewers are almost entirely outside the government and predominantly in universities. Thus even if a policy of transferring funding to industry were set it would be likely to be negated by the peer review process. In the past year the peer review system has come under attack and two studies of the NSF system are currently under way. The Agriculture Department's R&D has a history going back over a hundred years. Historically it has been tied to the State university system. Here too we have a considerable inertia and a counterbalancing force outside of government. The Agriculture research system is also currently under attack and the subject of a study by the National Academy of Sciences. The increase in the Commerce Department budget comes largely (39.9 out of 49.2 millions) from an increase in the NOAA budget. Efforts are currently underway to convert a greater portion

of the NOAA effort from in-house to contract. The HEW budget is large and has a smaller than average proportion of industrial funding. As with NSF the HEW institutes have a peer review system for grants. The reviewers, as with NSF, come largely from outside government and from the universities. Also, as with NSF, the peer review system is under attack and the object of study by an internal committee. The Defense Department contracting system, by contrast, is almost entirely (with the possible exception of the Air Force Office of Scientific Research and the Office of Naval Research) a system where decisions are made internally, and without outside review. In the past year the recommendations of outside advisory boards have not only been ignored but decisions regarding Air Force laboratories have gone completely counter to these recommendations. It appears that the presence of independent review can modify decisions. Perhaps we should remember the comments in the "Federalist," paper number 51, to the effect that our government guards against the abuse of power by any one group or individual by using the conflicting self-interests of many groups. Finally, we may note the recent comment by an OMB official (Federal Times, January 26, 1976, p. 24) that there is "good argument" for turning over the Veterans Administration (which has no industrial funding) hospital system to private contractors.

Since the Defense Department provides about two-thirds of the industrial funding, what is happening can be seen most clearly in the changes taking place in that budget. In the following table I give the budgets, both total and for industrial funding, in FY74, 75 and 76, and the derived changes in those budgets. The increase from FY75 to 76 is much greater for both than for FY75 to 74. The increase in total budget for FY75-76 is a factor of four greater than that for FY74-75, but the corresponding factor for the industrial part of the budget is a factor of almost seven. To show this in a somewhat different way, the last column shows the percentage of the increase in total budget going to industry for the two periods. For FY74-75 this is 51%, while for FY75-76 this is 88%. Thus for this latter period, FY75, 76, not only is there a very large increase in dollars compared to the previous year, but almost all of this increase is going to industry.

Budget increases, FY74, 75 and 76 for DoD

FY	Total (millions of dollars)	Δ_B	Industrial (millions of dollars)	Δ_I	Δ_I/Δ_B (percent)
74	8420.4		5266.1		
		439.1		225.5	51.36
75	8859.5		5491.6		
		1775.8		1561.7	87.94
76	10635.3		7053.3		

In order to clarify the changes in the DOD RDT&E budget over the different fiscal periods, I have converted the current dollar values for the period FY74-77 to constant dollars. As deflators I have used the values given by the DOD Comptroller, Mr. McClary, for the years FY74, 75, and 76 (FY 1976 Budget Hearings, Part I, p. 528), used for total obligation authority, since these should represent the figures used for estimates. For FY77 I have estimated an inflation rate of 7.0%, and for FY7T I have simply averaged the values for 1976 and 1977. The resulting constants are: 1974, 1.000; 1975, 1.133; 1976, 1.228; 197T, 1.271; and 1977, 1.314. Using the constant dollars calculated from these values the following table of percentage changes for each type of performer for the different fiscal periods is obtained:

PERCENTAGE CHANGE IN BUDGET BY TYPE OF PERFORMER

	74-5	75-6	76-7T	7T-77	76-77	74-77
Industry	- 7.39	+16.42	+2.75	+0.06	+2.81	+10.85
Gov't. In-House	- 6.43	- 3.83	-2.44	-3.19	-5.56	-15.01
FCRC's	- 6.38	- 1.16	-2.51	+2.52	-0.05	- 7.51
Universities	-12.23	- 2.67	+2.10	-4.58	-2.57	-16.77

What is perhaps most striking about this table are the values for the entire period FY74-77. It appears likely, looking at these figures, that targets for the entire period were set. Industry gains about 10% in constant dollars, in-house and universities lose about 15% in constant dollars, and the FCRC's lose about half the in-house and university amount, or about 7.5%. For each different fiscal period when there is a large gainer or loser, all the others gain slightly (in current dollars). For any given period one group appears to gain (in current dollars) at the

same time as another group loses. Thus, of the three overall losers, there is no period in which all are simultaneous losers. The advantages of this in reducing dissent are obvious.