Department of Defense R & D in the University

The Department of Defense designs its R & D programs intelligently so that they meet projected military needs.

Stanton A. Glantz and Norm V. Albers

Since World War II, universities in the United States have received substantial sums of money from the Department of Defense (DOD) to pay costs of scientific and technological projects. In the years immediately after the war, the military—in particular, the Office of Naval Research—was the preeminent source of support for academic science in a broad range of disciplines. Subsequently, other agencies developed research budgets, but the DOD still remains a major, and sometimes, dominant, source of money for scientific research. The availability of these large sums of money led many universities to adopt policies that would encourage faculty members to develop research interests that would be "fundable"; and this, in turn, led to affluence and rapid growth in many areas of science.

This situation continued quietly until the movement against the Indochina war gathered strength and increasing numbers of people began to question the role of universities in the war. This questioning often grew into acrimonious and occasionally violent debate on the nature and propriety of R & D done in the university under contract with the DOD. Opponents of DOD projects argued, on political and moral grounds, that individual responsibility required scientists to take a moral stand against U.S. policy in Indochina by refusing to work on military projects. Backers of DOD projects argued that the DOD supported projects solely on their scientific merits and that investigators supported by the DOD were simply engaged in an unbiased search for scientific truth which happened to be funded by DOD, not in projects that would benefit military operations in Indochina. Thus, the debate was focused on the merits and morality of specific individuals or laboratories connected with specific contracts or grants, not on the overall effects and implications of DOD funding on science, scientists, or universities.

To resolve this controversy we, with other investigators, studied all the DOD contracts at Stanford University active on 9 February 1971 (*1*). On that date, Stanford faculty members held 96 research contracts (worth \$12.6 million) and 15 development contracts (worth \$1.5 million). We found that individual scientists paid with DOD money did indeed view themselves as being involved in objective searches for scientific truth and that they did not consider their searches to be intimately connected with the immediate military problems in Indochina. We also found that the DOD supports research to obtain capabilities for which military planners foresee a need, and supports development to implement these capabilities in terms of specific military systems. Our study demonstrated that the military had developed a rational, well-administered program to define research priorities in terms of current and projected military needs and to purchase R & D from universities based on these needs. Thus, while the scientific process as reflected in each individual project proceeded objectively, funding availability biased scientists' choices on which projects to pursue.

The situation represented by the system of DOD sponsored work at Stanford raises serious questions about the university's efforts to fulfill its role of protecting the processes by which people search for scientific truth. For nonscientific standards set outside the scientific community to have a heavy influence on the choice of which projects are undertaken may be proper and desirable for industry or government; but, if one believes that universities exist in part to foster the unbiased development of human knowledge, it is not compatible with the universities' role as agency to protect the scientific process.

A DOD position paper (*2*) summarized our study of Stanford's 111 DOD contracts and grants:

> The report contains a project-by-project review of the content of about 100 Stanford Defense research projects, examining the military as well as the scientific objectives, and includes comments offered by research faculty members who were invited to contribute. The authors compared the university descriptions of each project . . . with the abbreviated description filed in the Defense Documentation Center [(DDC) (Fig. 1)]. . . . Great differences were found in statements of military objectives; in many cases the DDC statement contained a highly relevant objective for each project written by the DOD project monitor, while the university proposals, written by faculty researchers, largely ignored this point. A very simple explanation for these differences can be obtained by examining the research support brochures from defense agencies, . . . for these are the brochures regularly supplied to universities detailing the content requirements of research proposals. . . . None of the current brochures require the university faculty member to describe the military relevance of his proposed research [(*3*)]. . . . On the other hand, it has become common practice within the defense agencies to utilize the DDC statements in screening projects for relevance. . . . From these two different practices it can be seen that the discrepancies reported . . . are those which should have been expected to arise, and no more than that. There is therefore some truth in the allegation that the passage of the "Mansfield Amendment" provoked these differences. The need to more carefully delineate the military relevance of defense research projects was emphasized by the military departments during the FY 1970 review of all the current research projects.

The Mansfield Amendment to the "Authorization for Military Procurement, Research and Development, Fiscal Year 1970, and Reserve Strength" states (*4*): "None of the funds authorized by this act may be used to carry out any research project or study unless such a project or study has a direct and apparent relationship to a specific military function or operation." While the Mansfield Amendment forced the DOD to "more carefully delineate the military relevance of defense research projects," it did not significantly affect the nature

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of DOD sponsored work at Stanford. Most contracts active on 9 February 1971 originated before the amendment and already met the test of having "a direct and apparent relationship to a specific military function or operation."

The DOD's university programs are well organized and well administered to support the Armed Services' missions. The DOD need not coerce individual faculty members to work in areas of military technology; indeed, the DOD receives mostly unsolicited proposals (*5*). Since the DOD receives four to ten times as many proposals as it can fund, it merely selects those projects which fit its needs. There are nonmilitary applications of much DOD sponsored R & D but, when one assesses the nature of DOD research in the university, this random civilian "spillover" must be contrasted with the systematically organized program to develop military technology that underlies every DOD decision to fund or not to fund a proposal.

How the Military Selects Proposals

The DOD purchases research to develop capabilities needed for its current and projected operational requirements, not to build a generally strong technology base for the nation. Such requirements ultimately justify each contract. In defining military requirements and linking them to military research objectives, each service completes four stages (*6*): (i) Analysis of actual performance of military tasks (for example, can a foot soldier communicate with his commander?), which leads to operational objectives. (ii) The related systems division or military laboratory translates operational objectives into systems objectives (for example, a new piece of communications equipment). (iii) The systems command uses the systems objectives to generate technical objectives (micropower integrated circuitry). (iv) Finally, the research office (the Army Research Office) compares these technical objectives with the present status of applicable technologies and R & D resources to design a set of research objectives, which, if successfully realized, will yield the needed technical capabilities. Contact monitors in the research offices use these objectives, listed in the Army's *Military Themes for Oriented Research of High Scientific Merit* (*7*), in the *Air Force Research Objectives* (*8*), and in the *Naval Research Requirements* (*9*), to decide which proposals are worth funding [for example, the Stanford contract, "Micropower Integrated Circuits" (*10*)].

The research offices are organized into sections paralleling the services' research objectives, with competent technical specialists heading each section. They administer a two-part review process to choose proposals to fund (*11*). After receipt, several referees selected by the National Academy of Sciences–National Research Council consider the proposal's scientific merit. Simultaneously, scientists in the military laboratory supporting work on systems which require the new capabilities judge whether or not successful completion of the proposed work will help their work. Both the National Research Council's determination of scientific merit and the military laboratory experts' judgment of relevance must be affirmative or DOD will not fund the proposal.

Research Contracts: Two Examples

Tracing DOD sponsored research back to military operations is difficult because operations, systems, and technical objectives are classified. However, we know these connections exist because a contract monitor must declare that a proposal promises to fulfill some technical requirement listed in the classified *Technical Objectives Document* when he recommends funding (*12*). Sometimes the operations, systems, and technical objectives appear

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                    UNCLASSIFIED
        DDC REPORT NUMBER CT5551, APR 28, 1971
                   DDC FORMAT  B0075

TITLE:  (U) INVESTIGATION AND DEVELOPMENT OF CRYOGENIC MICROWAVE
 DETECTORS, NUCLEAR GYROSCOPES, ACCELEROMETERS AND MAGNETOMETERS

PERFORMING ORGANIZATION               RESPONSIBLE GOV'T ORGANIZATION
NAME                                  NAME
  STANFORD UNIVERSITY                   AF OFFICE OF SCIENTIFIC RESEARCH
                                        NPP
ADDRESS                               ADDRESS
  STANFORD CALIF                        1400 WILSON BLVD, ARLINGTON, VA
                                        22209

PRINCIPAL INVESTIGATOR:  FAIRBANK W

PRIMARY NUMBER CODE
 61102F       9767        04          0

CONTRACT/GRANT NUMBER        DATE OF SUMMARY  SECURITY:  SUMMARY  WORK
 F44620-70-C-0021              10 FEB 71                    U       U

SCIENTIFIC AND TECHNOLOGICAL AREAS
 012300   PARTICLE PHYSICS
 013600   QUANTUM THEORY

TECHNICAL OBJECTIVE:  (U) THE DETECTION OF TRUCKS, WEAPONS AND OTHER
 MAGNETIC OBJECTS IS A MAJOR PORTION OF THE USAF TACTICAL SUPPORT
 MISSION, PRESENT MAGNETIC DETECTORS ARE NOT SUFFICIENTLY ACCURATE
 OR RELIABLE TO BE HIGHLY EFFECTIVE, THIS RESEARCH SUPPORTS BASIC
 DEVELOPMENT OF A 3 AXIS FIXED FIELD AND GRADIENT MAGNETOMETER WHICH
 WILL HAVE THE CAPABILITY OF DETERMINING BOTH THE POSITION AND
 STRENGTH OF WEAK LOCAL SOURCES EVEN IN THE PRESENCE OF A STRONG
 BACKGROUND. THE MAGNETOMETERS WILL BE SENSITIVE TO FIXED FIELDS AND
 GRADIENT OF TEN TO THE MINUS ELEVEL GAUSS AND WILL BE ABLE TO BE
 REFERENCED TO ABSOLUTE ZERO, SUCH DEVICES WILL ALSO BE USEFUL IN
 DETERMINING THE MAGNETIC PROPERTIES OF MATERIALS AND THE
 EFFECTIVENESS OF SUPERCONDUCTING MAGNETIC SHIELDS, A SECOND USAF
 REQUIREMENT IS FOR EXTREMELY ACCURATE ACCELEROMETERS TO BE USED FOR
 NAVIGATION AND GUIDANCE, AND POSSIBLY FOR VARIOUS DETECTION
 SYSTEMS, THIS RESEARCH ALSO SUPPORTS THE BASIC DEVELOPMENT OF A
 SUPERCONDUCTING ACCELEROMETER WHICH WILL BE SENSITIVE TO 10 TO THE
 MINUS TWELVE G IN EACH OF 3 AXES, WITH AN ARBITRARY ZERO LEVEL
 CAPABILITY. THE WORK UNDER THIS ADDITIONAL SUPPORT WILL BE AN
 EXPANSION OF THE PROGRAM FUNDED UNDER F44620-70-C-0221.

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Fig. 1. Typical statement of the Defense Documentation Center.

in congressional hearings, as with the Army helicopter program (*13*, part 1, p. 719):

Our R & D effort in support of our activities in Southeast Asia continues. In this war without battle lines . . . our helicopter developments have provided improved mobility in terrain that presents numerous obstacles to conventional land movement. . . . Air mobility is our first priority for R & D in the Army. Our primary effort in this area is directed toward the development of an attack helicopter. It is a part of the evolutionary concept of using an aerial platform for close support and antitank missions [(*14*, part 6, p. 30)]. . . . As the preeminent employer of rotorcraft, we must continue and increase our R & D support of these vehicles which are uniquely suited to Army use. We plan a broad technology program encompassing the design and demonstration of new concepts in rotors, innovations in rotary wing aircraft designs, and maintainability and reliability. We require a rotary wing technology base equivalent to that of fixed wing aircraft. . . .

The *Proceedings of the Chief Investigators' Conference and Review of the Military Theme "Helicopter and V/STOL* [vertical and short takeoff and landing aircraft] *Aircraft Research"* reflects further systems objectives and technical requirements (*15*):

Over the next few years the Army proposes to develop several new aircraft . . . the Advanced Aerial Fire Support Systems, the Heavy Life Helicopter, the Utility Tactical Transport Aircraft System, and the Manned Air Vehicle for Surveillance. To provide demonstrated technology to support these aircraft system developments, the Army is funding efforts in advanced rotary wing technology, maintainability and reliability, propulsion, survivability, noise reduction aerial weapons, night vision, advanced fire control systems, and advanced navigation and control systems.

Looking toward our new aircraft, here are some of the problems to which we seek solutions: rotary wing aerodynamics and dynamics, . . . materials that improve the survivability, reliability and economy of rotary wing aircraft, . . . reduce the noise of rotor craft without penalizing performance, . . . gas turbine engines of high power-to-weight ratio with improved reliability, . . . improved stability and contollability for V/STOL aircraft.

In hearings before the Senate Armed Services Committee (*13*, part 1, p. 804) the Army gives a breakdown of 32 budget items relating to helicopter development, including programs in propulsion, structures, weapons, guidance, surveillance, and target acquisition. The first entry in the list, the research program "Mechanics: IF061101A33F-Research in Aeronautics," supports Stanford's contract, "Research in Aircraft Structural Analysis and Design." The code number appears on the contract's DDC statement, which describes the work as "development of structural analysis and design criteria for the application of advanced composite materials to future Army rotary wing and V/STOL vehicles" (*16*).

Stanford holds two other Army helicopter contracts. Since the National Aeronautics and Space Administration (NASA) Ames Research Center funds them through a reciprocal agreement with the Army Air Mobility Research and Development Laboratory, there are no DDC statements available to yield project numbers; however, their place in this Army effort is easily discerned. The "Basic Studies in Aerodynamic Noise" contract (*17*) relates to the problem of excessive helicopter rotor noise. John Foster, director of Defense Research and Engineering, cited this example (*14*, part 6, pp. 33–36):

An OH-6 helicopter was modified so that its noise was reduced to less than current levels. In particular, this OH-6 can be flown overhead and be essentially inaudible against many backgrounds. This can be a major factor in reducing helicopter vulnerability to detection.

The second contract, "Study of the Dynamics and Control of Rotary-Wing VTOL Aircraft" (*18*), was aimed to produce techniques for aerial platform stabilization and for flight path control and optimization. The Army's "aerial platform for close support and antitank missions" requires these techniques. Helicopter technology illustrates how military operational objectives (moving soldiers and equipment easily in difficult terrain) lead to system formulation (the Utility Tactical Transport Aircraft System), technical objectives (improved structural analysis; new materials, such as composites for lightweight construction; control techniques for better flight performance), and finally research directions.

In both of these examples, the DOD and the researcher seek the same final result. In other cases, however, DOD is not concerned with the researcher's final result, but rather the process or technology he uses to achieve it. Thus, the Navy supports Stanford's superconducting accelerator program (*19*) even though there are no apparent military applications for most of the physics done with the accelerator's electron beam (*20*). To accelerate the beam, a substantial amount of electromagnetic energy must be transferred at microwave frequencies, a process made more efficient by cooling the system to liquid helium temperatures, where the components become superconducting. Robert A. Frosch, Assistant Secretary of the Navy for Research and Development explained (*13*, part 2, p. 1505):

. . . how scientific work which sometimes doesn't have—for everyone—an obvious connection to military missions can frequently be seen to have such a connection. For example . . . this large scale refrigerator for operating at very, very low temperatures means that we can build electronic systems which will be much more compact, reliable, and efficient. The cryogenic technique would permit a great advance in certain kinds of radar and electronic warfare systems. The fact that we can build this refrigerator on this scale means that it will probably become a practical matter to obtain high efficiency in the transfer of electromagnetic radiation on board ship.

While we do not have the resources to trace every contract back to a military operational requirement, we can identify the military research objectives they are funded to meet. This identification process is similar for Air Force and Navy contracts, but somewhat different for Army contracts. The Army describes its research needs in 51 "military themes" (*7*), as "Ceramics for Structural Use," "Gas Dynamics of Missiles and Projectiles," or "Helicopter and V/STOL Aircraft Research." In contrast, the Air Force (*8*) and the Navy (*9*) divide their research needs by major scientific discipline (*21*). Either singly or in small groups, research contracts comprise code number "projects" in the booklets of both services. (Projects, which are lowest on the DOD budget's scale, include many contracts, called "work units," given on a competitive basis to industry and university researchers.) The DDC statements include project codes; the four-digit entry under "primary number code" (see Fig. 1) enabled us to match all but six contracts with their military research objectives (*22*).

The Development Contracts

In comparison with research contracts, development contracts are one step closer to the creation of operational military hardware or capabilities. Whereas the military significance of a research contract follows from its associated technical objectives, the significance of development contracts lie in their systems objectives. In other words, DOD purchases research to create technical capabilities; development to implement them. The military laboratory or systems command responsible for developing and testing components or finished hardware, not the service's research agency, lets development contracts. Industry (such as the Rand Corporation) and military laboratories hold 95 percent of development contracts. Universities hold the remaining 5 percent (*13*, part 1, p. 323).

Faculty members hold contracts for each of three types of development: (i) exploratory development, which "is pointed toward specific military problem areas with a view toward developing and evaluating the feasibility and practicability of proposed solutions and determining their parameters"; (ii) advanced development, which includes "all projects which have moved into developing hardware for experimental or operational test; the design of the items is directed toward hardware for test or experimentation as opposed to items designed and engineered specifically for eventual military use"; (iii) engineering development, which describes "those development projects being engineered for military service use but which have not yet been approved for procurement or operation" (*23*).

As with research, detailed information showing the military importance of development contract work is classified, but we can occasionally deduce this connection from sources besides the DOD. For example, the trade journal, *Microwaves and Laser Technology*, devoted an issue to electronic warfare (*24*). The section "Surface Acoustic Waves: New Processing Tools for Electronic Warfare" outlined why these devices are being developed (*24*, p. 46) (our italics):

> An effective electronic warfare system requires the ability to identify the various elements in a hostile environment and to take appropriate action against them. In the two key areas of this problem, measurement of threat frequencies and *deception of hostile radars*, acoustic surface wave devices offer the prospect of dramatic improvement in system capability. . . . Specifically, those surface wave devices which should find wide utility in Electronic Warfare systems include *discretely variable delay lines for coherent range deception*, banks of miniature bandpass filters for discriminator front ends, and large time-bandwidth dispersive delay lines for compressive receivers.

"Coherent range deception" is an electronic countermeasure used to confuse a hostile radar by giving it false information about its distance from a target. (The hostile radar judges distance by measuring the time it takes a radar pulse to propagate out, bounce off the target, and return. If the target contains a device which "records" the incoming signal, delays it briefly then retransmits it, the target appears farther from the hostile radar.) Microwave acoustic delay lines are vital to this process (*24*, p. 50):

> A range deception repeater is required to respond simultaneously to a wide band of radar signals over extremes of both airborne and shipboard environments, and in turn retransmit deceptive and erroneous range information. Range deception may be accomplished by means of a variable delay line which permits the delay of each incident pulse by an increasing amount. The end result of this operation is confusion of the tracking radar causing it to "break lock" on the target. . . . The problems which must be conquered include reduction in the costs of materials, reduction of insertion loss, the achievement of higher frequencies of operation and the extension of achievable time delay or processing time . . . much of the insertion loss may be eliminated by means of unidirectional transducers such as those developed at Stanford University.

Both the Navy (*25*) and the Air Force have exploratory development contracts supporting this work: the latter sponsors the contract "Microwave Device Techniques for Aerospace Users" (*26*), the former sponsors "Research on Devices Using Acoustic Surface Waves" (*27*).

Two Different Perceptions

These typical examples demonstrate that DOD intelligently supports research and development to further progress toward well-defined military objectives or, in the case of development contracts, contribute to specific projects. Most faculty members see the situation differently. Consider this example of how researchers and the DOD perceive the same work differently. The Army Research Office's DDC statement describes a contract, "Fundamental Investigation of Amorphous Semiconductors and Transition Metal Oxides," as a study (*28*)

> to obtain fundamental information concerning amorphous semiconductors and transition metal oxides. This research is concerned with the influence of the disorder in amorphous semiconductors on the ability of their [sic] materials to effect the emission of electrons through radiation which is a crucial function of the materials used in photocathodes in night viewing devices.

The principal investigator objected to this description of his work; he wrote (*29*):

> The DDC statement . . . is a misstatement of the facts. As can clearly be seen from the proposal, all reports, and the publications which have been issued, absolutely no connection can be made between the studies being done here and the "ability of their materials to effect the emission of electrons through radiation which is a crucial function of the materials used as photocathodes in night viewing devices.

The military theme statement on night vision work elucidates the Army's context for funding this work and possible origins of the DDC phraseology (*7*, p. 52):

> Tactical superiority in military operations at night depends on the ability of the soldier to operate effectively. An important adjunct to his effectiveness is to provide perfect night vision without revealing the location of the observer, and to develop techniques which are not affected by countermeasures. . . . The total night vision research program includes basic and applied research studies related to four specific areas: image intensification, optical and infrared radiation, far infrared detection, and visionics (the analysis and performance of night vision systems and their interaction with man).

The Proceedings of the Chief Investigators' Conference and Review of the Military Theme "Research on Night Vision" (*30*) adds insight into the Army's motivation. Benjamin Goldberg, director of the Night Vision Laboratory (NVL) is reported as saying in his opening remarks (*30*, p. 3) that he

> . . . recalled the very successful meeting held in 1968, and hoped that the present audience would continue to be stimulated in areas of research of interest to the NVL. . . . He stated that the NVL knows the importance of research since without the fruits of research, systems work stalls and comes to a stop. He pointed to . . . areas in which long-term research has been very important such as in the third-generation photocathode work. . . . He hoped that the presentations by NVL personnel during the session before the university papers were given would give the flavor of the work being carried on, and provide faculty members with a chance to tailor research to assist in NVL's efforts.

This contract's monitor, Robert Mace, whose job includes studying proposals and writing DDC statements certified (*11*) that, although the wording sounded stilted after computer processing, the DDC statement accurately indicated this research's relevance to Army requirements. He also said that the statements *were* written in response to congressional pressure to demonstrate the military relevance of DOD sponsored research. This did not mean that the Army justified their projects after the fact. Rather, the DDC statements express in writing the same principles under which funding had been granted prior to the Mansfield Amendment.

Mace referred us to John Dawson, the chief scientist of the Army Research Office, who said he could see how the principal investigator did not consider the DDC statement to represent accurately *his perception* of research, but that the criticism was incorrect when claiming that there was "no connection to be made." He summarized the difference between his and the investigator's view by observing, "Basic research, like beauty, is in the eye of the beholder" (*31*).

A Realistic Perspective

We have seen how academic research and development fits into DOD programs. In an interview, Marshall Harrington, an Air Force contract monitor, Elliot Weinberg, director of Scientific Research, Office of Naval Research, and Edward Reilley, assistant director of Defense Research and Engineering, accurately described DOD's relationship with the university (*32*) (our italics):

The Department of Defense makes a very thorough effort to insure funding only research projects directly relevant to the military's technological needs. Not only is there direct pressure from the Congress to get the best possible return on every dollar spent, there is a sufficiently large number of research proposals received so that the funding agencies can afford to choose only those most nearly matching their goals. The ratio of proposals received to those accepted is anywhere from four to one to ten to one, varying from one research agency to another.

The DOD is not simply accepting scientific and technological products coming from a random pattern of independent research activities in the universities. Rather DOD interest in some particular area can stimulate growth and development planned to fill specific short-term and/or general long-term technological gaps in the military's capability. Thus, given the large amount of funds involved, and the large percentage of all engineering research these funds account for, the DOD plays a powerful role in shaping the profile of engineering research at Stanford and many other universities. This effect can be either quantitative or qualitative. In the absence of DOD interest laser physics would not enjoy the level of support it now receives at Stanford; funding by another agency, such as the National Science Foundation, would probably be allocated to different types of projects. Theoretical statistics could not have developed in the same areas it has over the past decade.

It is the responsibility of those making the higher level decisions on the directions of research funding to maintain a comprehensive understanding of the present state of technology and the relations, both actual and potential of many specific technologies to military problems. *This expertise, maintained by constant study of all the major technical journals, industrial reports, and information from both civilian scientific advisory boards and military planners, gives these men a more complete and far-reaching vision of the technical and systems possibilities toward which research planning can be directed than that enjoyed by most researchers in the industrial or academic sectors of the R & D establishment.* The direct link of DOD contract funding is more efficient for these purposes than having the same or similar work supported by other agencies such as the NSF [(*33*)]. Meetings are periodically held between top representatives of DOD, NSF, AEC, and NASA to apportion research areas in the most appropriate manner.

Once a particular project is decided upon there are a number of additional criteria bearing on the decision to fund a proposal. The work must hold intrinsic promise of high quality, judged both by the proposal and the background of the investigator. The latter should be in an environment stimulating his research, for example, there should be adequate facilities, competent workers (laboratory staff, graduate students, and so on) and colleagues with whom ideas can be exchanged and developed. *The extent to which a project aids the educational function of the university is not important in the decision to grant a contract. This is presumably a consideration of the university in approving and forwarding the proposal.*

Our study of all Stanford's DOD contracts supports these statements. They represent a reasonable understanding of the relationship between Stanford University and the DOD.

Summary

The DOD carefully evaluates its technical needs and executes programs of sponsored research and development to fulfill them. Thus, while individual projects proceed in accordance with established scientific principles of objectivity, the overall system of DOD funding allows the military to influence the development of science technology. Many have argued that this system of contracts and grants has well served science and the universities. One cannot deny that the influx of money led to rapid progress in selected scientific fields and increased scientific institutions' affluence. With this fact we have no quarrel. However, these same people often continue to argue that the systems of federal funding for science, specifically DOD funding of science, follows merely on the work's scientific merit, not on how it fits any larger scheme. They continue, that, since DOD supports good science for its own sake, the combination of military money and universities strongly encouraging faculty to seek that money encourages healthy competition for faster scientific progress. The DOD's approval process is seen to follow from the scientist up, with the military deciding which proposals for research have the most intrinsic (scientific) merit, then after the fact, thinking up a military justification for congressional budget requests. It is this latter belief with which we take issue. The DOD considers the scientific worth of the proposals for research it receives, but only after it has determined that the proposal fulfills a specific military need.

This fact and its implications for the university as an institution charged with protecting the process by which man discovers new knowledge have been ignored in the debates over DOD sponsored research and development in universities. In addition, the Nixon Administration's efforts to tighten management controls over civilian research, especially in the biomedical and energy areas, promises to further undermine the university's role as an institution charged with fostering a search for truth free from bias in both methodology and subject selection.

References and Notes

1. Stanford Workshops on Political and Social Issues (SWOPSI) sponsored this study. SWOPSI, a program of student-initiated courses, has sponsored over 200 workshop courses for credit during its 5 years of existence. For more details, see S. A. Glantz, C. A. Farlow, R. A. Simpson, N. V. Albers, D. E. Pocekay, W. E. Holley, M. F. Becker, S. S. Ashley, M. R. Headrick, *DOD Sponsored Research at Stanford*, vol. 1, *Two Perceptions: The Investigator's and the Sponsor's* (SWOPSI, Stanford, Calif., 1971); N. V. Albers, S. S. Ashley, M. F. Becker, C. A. Farlow, S. A. Glantz, R. A. Simpson, *DOD Sponsored Research at Stanford*, vol. 2, *Its Impact on the University* (SWOPSI, Stanford, Calif., 1972). Copies of these publications are available from SWOPSI, 590A-Old Union, Stanford University, Stanford, Calif. 94305.
2. Department of Defense, *Analysis of the Origin of "A Rose by Any Other Name May Be Defense Research,"* Department of Defense position paper on *DOD Sponsored Research at Stanford* (*1*, vol. 1) (Department of Defense, unpublished paper, 7 September 1971). Written in response to United Press International stories on the same publication that were printed in the Washington *Post* and Washington *Star*, 5 August 1971.
3. A news article [D. Shapley, *Science* **175**, 866 (1972)] on our study (*1*, vol. 1) stated: "Why is DOD reluctant to require scientists to come forward and state military uses of their work? Laird explained that it might cause DOD to lose top scientific talent and research. In an interview [with *Science*], Edward Reilley, assistant director of Defense Research and Engineering, said it would 'advertise' DOD's weaknesses. 'We don't believe it's

possible for any faculty member to be versed in DOD's needs.' As for faculty who seek support from DOD telling their campus constituency that their work has no military uses, Reilley saw no need to "punish" those 'few' by requiring a statement. Whether a 'few' of the faculty at Stanford need their knuckles rapped, however, is a relatively minor matter. The main point is that DOD now exempts all scientists from grappling with the key moral issue of the uses to which their research results will be put."

4. *Hearings Before the Committee on Armed Services, United States Senate, 91st Congress, 2nd Session on S3376 and HR17123* (Government Printing Office, Washington, D.C., 1970), p. 159. See S. A. Glantz *et al.* (*1*, vol. 1, pp. 29–37) or R. W. Nichols, *Science* **172**, 29 (1971) for more discussion of the Mansfield Amendment.
5. It is not uncommon for DOD representatives to suggest projects to faculty, but we have discovered no arm-twisting when the faculty member does not express an interest. Much informal communication often occurs between the faculty and their DOD task monitors. Stanford's engineering school recognizes and encourages this communication: "A strong and direct contact between the principal investigator and the research sponsor (technical staff mainly) must be developed and maintained throughout the contract period to guarantee the optimum coordination of interests, transfer of results, etc. (This evidence of personal interest is of most genuine value when contract renewal time again approaches.)" [Stanford School of Engineering, *Sponsored Research in the School of Engineering—The Role of Research Coordination* (Stanford Univ., Stanford, Calif., 1968), p. 4].
6. E. Reilley, assistant director of Defense Research and Engineering, interviewed by N. V. Albers, 24 August 1971.
7. U.S. Army Research Office, *Military Themes for Oriented Research of High Scientific Merit* (U.S. Army Research Office, Durham, N.C., 1970).
8. Air Force Systems Command, *Air Force Research Objectives, 1971* (Air Force Systems Command, Washington, D.C., 1970).
9. Office of Naval Research, *Naval Research Requirements* (Office of Naval Research, Arlington, Va., 1970).
10. S. A. Glantz *et al.* (*1*, vol. 1, p. 196). In the contract the investigator agrees to ". . . conduct investigation in accordance with integrated Electronics Division Technical Guidelines for Micropower Integrated Circuits for Portable Equipment. . . ." Principal investigator: J. Meindl.
11. R. Mace, director of the Physics Division, U.S. Army Research Office, Durham, N.C., interviewed by N. V. Albers, 25 August 1971.
12. M. Harrington, contract monitor at the Air Force Office of Scientific Research, interviewed by N. V. Albers, 24 August 1971.
13. *91st Congress, 2nd Session, Senate Committee on Armed Services, Hearings on "Authorization for Military Procurement, Research and Development, Fiscal Year 1971, and Reserve Strength."*
14. *92nd Congress, 1st Session, House of Representatives Subcommittee of the Committee on Appropriations, Hearings on "DOD Appropriations for 1972."*
15. U.S. Army Research Office, *Proceedings of the Chief Investigators' Conference and Review of the Military Theme "Helicopter and V/STOL Aircraft Research"* (U.S. Army Research Office, Durham, N.C., 1970), pp. 4–5.
16. See S. A. Glantz *et al.* (*1*, vol. 1, pp. 188–189). Principal investigator of this project: J. Mayers.
17. ———, *ibid.*, p. 162. Principal investigator of this project: K. Karamchetti.
18. ———, *ibid.*, p. 59. Principal investigator of this project: A. Bryson.
19. ———, *ibid.*, p. 139. Principal investigators of this project: R. Hofstadter and W. Fairbank.
20. For a good discussion of this issue, see B. T. Feld, G. W. Rothjens, S. Weinberg, Eds., *Impact of New Technologies on the Arms Race* (MIT Press, Cambridge, Mass., 1971).
21. G. Hansen, Assistant Secretary of the Air Force for Research and Development, testified: "Our research has a great diversity because the Air Force must do many different things to carry out its mission. But while our research is comprehensive to our needs, it is not encyclopedic. We don't support broad research programs in genetics, in botany, in geriatrics, in oceanography, in automotive engineering, on highways, or in other areas which either have been assigned to some other sponsor or which have little direct and apparent mission applicability to the Air Force." (91st Congress, 2nd Session, *Senate Appropriations Committee Hearings on DOD Appropriations, Fiscal Year 1971*, part 4, p. 563.
22. Although Air Force and Navy projects are analogous to Army "military themes," Army project numbers are not included in its research booklet. Therefore, in matching Army contracts to military themes we made educated guesses, usually obvious choices. See N. V. Albers *et al.* (*1*, vol. 2, pp. 20–38) for a list of Stanford research contracts and corresponding military research objectives.
23. *91st Congress, 1st Session, House of Representatives Subcommittee of the Committee on Appropriations, Hearings on "DOD Appropriations for 1970"* part 5, p. 673. All the research contracts are funded under one budget program element, Defense Research Sciences, designated "61102." On the other hand, development contracts are parts of different program elements, identified by different numbers (exploratory development numbers begin with 62, advanced development, with 63, engineering development with 64). Just as research contracts have project numbers within the Defense Research Sciences program, so development contracts are further identified by project numbers. These numbers appear on the DDC statements and in the DOD budget presented during congressional testimony. Thus, we associate each development contract with the mission of the military laboratory which let the contract.
24. *Microwaves Laser Technol.* **10** (No. 10) (October 1971).
25. R. Frosch, Assistant Secretary of the Navy for Research and Development, testified: "The major effect in shipboard electronic warfare has been directed against the antiship missile. To this end, a *Ship Anti-Missile Integrated Defense (SAMID)* program has been established to integrate discrete systems into a total ship system responsive to the command and control organization. . . . The airborne electronic warfare project are directed toward the self-protection of our attack and fighter aircraft, and to the development of information gathering systems that will lead to a still greater capability to provide projection" (*13*, part 2, p. 1521).
26. See S. A. Glantz *et al.* (*1*, vol. 1, p. 71). Principal investigator of this project: M. Chodorow. There was no DDC statement for this contract and no program number appeared on the contract document. However, in Senate Appropriations Committee Hearings, the Rome Air Development Center's "Ground Electronics Program" (62702F) is described with "Microwave Tubes and Devices" being one project (5573). On the following page all major contractors are listed, including Stanford. Since Stanford holds only one Rome Air Development Center contract, we conclude that the reference is to Chodorow's contract. (*21*, part 5, p. 673.)
27. See S. A. Glantz *et al.* (*1*, vol. 1, p. 242). Principal investigator of this project: H. Shaw.
28. Principal investigator of the project: W. Spicer. Based on the principal investigator's proposals, the current contract, and a questionnaire to the principal investigator, this work was summarized (*1*, vol. pp. 255–256) as follows:

   "Amorphous (disordered) semiconductors are being studied to determine their electronic properties and to compare them with the more fully understood crystalline materials. The principal tool of the study is photoemission (process by which electrons are emitted from a material when it is illuminated). Optical measurements are also made when they are needed. Electron transport and infra-red measurements are made at the Naval Ordnance Test Station at China Lake which has unique facilities in these areas.

   "In general, test materials will be chosen because fundamental questions regarding their electronic structures are still unanswered. Materials to be tested include pure amorphous Germanium and Germanium with group III and group V dopant. The Ge-Te system will also be studied 'since it is of practical interest as a memory device.'

   "The second half of the contract work is devoted to the study of transition metal oxides, crystalline materials. Of particular interest in this group is V_2O_4 which is an insulator below 67°C. and conductor above that temperature. Conventional energy band calculations predict that this material should be a good conductor. The experimental work is directed at understanding the cause of this peculiar phase transition. Other transition metal oxides similar in some ways to V_2O_4 will also be studied to gain perspective on the problem."

   (Material in single quotes from proposal for 24 June 1969 to September 1972.)
29. See S. A. Glantz *et al.* (*1*, vol. 1, pp. 255–256). After the publication of N. V. Albers *et al.* (*1*, vol. 2), W. Spicer issued the following statement: "Photoemitters that are important for practical applications fall into two classes. (1) The alkali-antimony photocathodes presently in use, and (2) The III–V materials such as GaAs which may become important in the future. The first class of materials is so different from Ge and normally contains such a high density of structural defects (over $10^{19}/cm^3$) that it seems highly unlikely that knowledge applicable to it can be gained from the study of amorphous Ge.

   "For the III–V materials, the photocathode becomes useless long before the defect structure approaches that of amorphous Ge. Therefore, I think that it is very doubtful that our work will contribute to night vision as suggested by a properly translated DDC statement. The possibility cannot be ruled out completely but I believe the work supported by the Army is no more likely to make such a contribution than that supported by the NSF or NASA."
30. U.S. Army Research Office, *Proceedings of the Chief Investigators' Conference and Review of the Military Theme "Research for Night Vision"* (U.S. Army Research Office, Durham, N.C., 1971). The proceedings include W. Spicer's paper, "Fundamental Investigation of Amorphous Semiconductors and Transition Metal Oxides."
31. J. Dawson, chief scientist of the Army Research Office, Durham, N.C., interviewed by N. V. Albers, 25 August 1971.
32. M. Harrington, Air Force contract monitor, Air Force Office of Scientific Research; E. Weinberg, director of Scientific Research at the Office of Naval Research; and E. Reilley, assistant director of Defense Research and Engineering, Office of the Director of Defense Research and Engineering, interviewed by C. A. Farlow, N. V. Albers, and M. F. Becker, 12 August 1971.
33. A study, Project Hindsight, conducted by the Office of the Director of Defense Research and Engineering and published in 1966 supports this claim. The researchers selected weapons systems, dissected them into subsystems and components, then "identified each contribution from recent science and technology which, in their judgment, is clearly important either to increased performance or to reduced cost, compared to a predecessor system. . . ." Each discrete contribution was called an "event." They concluded: ". . . that the relative efficiency of production of science and technology *events which have been utilized in defense is substantially higher when funded and managed by the Defense Department* or defense industry than it is when funded and managed by the non-defense sector of government or industry. . . . Thus, we see that although technological 'spin-off' into defense weapon systems from the non-defense sector exists, it is very small, and it is quite inadequate to produce the number of innovations needed to make possible the large increases in performance which have been attained" (our italics). [C. W. Sherwin, *First Interim Report on Project Hindsight (Summary)* (Office of the Director of Defense Research and Engineering, 30 June 1966).]
34. We thank the coauthors of *DOD Sponsored Research at Stanford*, vols. 1 and 2, and the others who assisted us with this work: C. Farlow, R. Simpson, D. Pocekay, W. Holley, M. Becker, S. Ashley, M. Headrick, H. Ashley, W. Rambo, E. Reilley, E. Weinberg, M. Harrington, R. Mace, J. Murray, J. Dawson, J. Yudken, R. White, E. Cilley, A. Abramowitz, M. Perl, H. Holman, W. Hayes, D. Harrison, and G. Hayes.