GOVERNMENTATTIC.ORG
Videre licet
- 2007 -

governmentattic.org

"Rummaging in the government's attic"

Description of document:	Report of the Defense Science Board (DSB) 1981 Summer Study Panel on Technology Base, November 1981
Requested date:	06-July-2017
Released date:	13-March-2018
Posted date:	30-July-2018
Source of document:	FOIA Request OSD/JS FOIA Requester Service Center Office of Freedom of Information 1155 Defense Pentagon Washington, DC 20301-1155 Fax: (571) 372-0500

The governmentattic.org web site ("the site") is noncommercial and free to the public. The site and materials made available on the site, such as this file, are for reference only. The governmentattic.org web site and its principals have made every effort to make this information as complete and as accurate as possible, however, there may be mistakes and omissions, both typographical and in content. The governmentattic.org web site and its principals shall have neither liability nor responsibility to any person or entity with respect to any loss or damage caused, or alleged to have been caused, directly or indirectly, by the information provided on the governmentattic.org web site or in this file. The public records published on the site were obtained from government agencies using proper legal channels. Each document is identified as to the source. Any concerns about the contents of the site should be directed to the agency originating the document in question. GovernmentAttic.org is not responsible for the contents of documents published on the website.

-- Web site design Copyright 2007 governmentattic.org --

DEPARTMENT OF DEFENSE
OFFICE OF FREEDOM OF INFORMATION
1155 DEFENSE PENTAGON
WASHINGTON, DC 20301-1155

MAR 13 2018

Ref: 17-F-1237

This is the final response to your enclosed July 6, 2017, Freedom of Information Act (FOIA) request for an electronic copy of "...1981 Summer Study on Technology Base (October 1981)". Your request was received in this office on July 17, 2017, and assigned case number 17-F-1237. We ask that you use this number when referring to your request.

Representatives of the Defense Science Board, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, a component of the Office of the Secretary of Defense (OSD), conducted a search of their records systems and provided the requested study document, totaling 233 pages (loaded to enclosed CD), determined to be responsive to your request. This record is appropriate for release in its entirety, without excision.

This constitutes a full grant of your request, and closes your case file in this office. There are no assessable fees associated with this response.

If you have any questions, please contact the Action Officer assigned to your request, Mr. David Swiney at david.k.swiney.civ@mail.mil or (571) 372-0427.

for

Stephanie L. Carr
Chief

Enclosures:
As stated

REPORT OF THE DEFENSE SCIENCE BOARD 1981 SUMMER STUDY PANEL ON TECHNOLOGY BASE

NOVEMBER 1981

OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ENGINEERING
WASHINGTON, D.C. 20301

This report has been prepared for limited release by deleting security classified supporting detail appearing in the full report of the Defense Science Board to the Secretary of Defense. These deletions, when substantial, are identified in the text. They do not affect general structure of the document or its findings and recommendations.

OPEN TO PUBLIC AS OF FEB 12, 2018 per
DEFENSE SCIENCE BOARD

~~Distribution limited to U.S. Government Agencies only. Test and Evaluation. Other requests for this document must be referred to ODUSDRE(R&AT), The Pentagon, Washington, D.C. 20301.~~

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE BOARD

28 December 1981

MEMORANDUM FOR SECRETARY OF DEFENSE
DEPUTY SECRETARY OF DEFENSE
CHAIRMAN, JOINT CHIEFS OF STAFF

THROUGH: UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

SUBJECT: Report of Defense Science Board Summer Study on the Technology Base

The attached final report of the Defense Science Board Summer Study on the Technology Base was prepared under the chairmanship of Dr. George H. Heilmeier. The study addresses the following issues: What technologies are critical to future (1990-2000) defense capabilities? Is the investment in the Technology Base adequate? Is the process of transition from technology base to weapon systems adequate? Are the universities able to support national security requirements? Are the available scientific and engineering personnel resources adequate to support defense technology requirements?

The principal findings of the study are that:

1. There is no strong, consistent, DoD-wide linkage between technology base investment strategies and the requirements of future combat.

2. Certain very high potential payoff technologies are not being adequately pursued in the current DoD technology base program.

3. There is insufficient funding for technology demonstrations which are an essential part of efficient technology transition.

4. The university research base relating to defense preparedness is in need of considerable enhancement in the areas of faculty, equipment, facilities, and support.

5. The DoD laboratories and DARPA afford a number of opportunities for increased effectiveness.

Specific recommendations are made by the study panel to address these critical areas; many of these recommendations I view to be especially imaginative and particularly promising of payoff.

In summary, this DSB report focuses attention on one of the nation's most important assets, its technology base. But, this is only an initial step which we strongly feel must be sustained at the highest level if improvements are to be made. We are giving dedicated attention to assisting in implementing the recommendations contained in the report. I recommend you review the Executive Summary.

Norm

Norman R. Augustine
Chairman

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

28 October 1981

DEFENSE SCIENCE BOARD

Mr. Norman R. Augustine
Chairman
Defense Science Board
Room 3D1034, The Pentagon
Washington, D.C. 20301

Dear Mr. Augustine:

Enclosed you will find the final report of the Defense Science Board Summer Study of the Technology Base. It treats in some depth all of the questions proposed for our consideration by Dr. DeLauer and will, in my opinion, make an important contribution to DoD's effort to upgrade the technology base. I think you will find the recommendations are to the point and can be implemented if given proper support.

As you can see from the report, we not only treated the topics assigned, but also accomplished something which may be of great value to DoD. Out of necessity, we were forced to create our own methodology for making decisions about the technology base - what to support, how to support it. The methodology can be characterized as a "top down" approach given certain assumptions about the nature of future war, with specific linkage of technology to systems and operational concepts. Criteria of relevance were established through a figure of merit designed to show priority based on a balancing of opportunity and risk.

Some of these factors are no doubt used by decision makers in DoD but what does not seem to be accomplished is the integration of all of these elements into a total package, a structured planning process which both provides the appropriate guidance and the necessary feedback. OSD and the Services have to take the initiative in implementing such an enterprise.

We recommend that DoD adopt such a structured methodology for its decision making. Whether or not the figure of merit or the criteria are exactly adopted is not the point. What is important is that decision makers at all levels should ask the questions which are summarized in the investment strategy catechism:

- What are we trying to do?
- How is it done today and what are the limitations of current practice?
- What is new in my approach and why do I think I can be successful?
- Assuming success, what difference will it make to the user or in a mission area context?
- How long will it take; how much will it cost; what are the "midterm" and "final" exams?

The answers to these questions should be of great value in the resource allocation process.

As you can see, we used this methodology to identify the top 17 technologies which we termed the "order of magnitude" technologies. We reiterate that we are not saying that these are the only ones worthy of support. There are certainly other technologies which should be supported by DoD. But we do feel that any technology should be able to stand up to scrutiny as a contributor to DoD's mission.

The Task Force also emphasized the critical problems of technology transition within the DoD. A number of barriers were identified which we believe inhibit the successful transition of technology into systems. There is little incentive to exploit new technology due to discontinuity of funding; indecision and the short term orientation of many key decision makers; organizational and spatial separation of technology base and systems people; and insufficient emphasis on technology demonstrations. A champion on the user side or user support is a key factor. In order to help DoD focus on this issue, the panel recommended several actions including the creation of an advanced projects agency staffed by Service personnel. However, even if the agency is not formed, there are important elements of this agency which should be undertaken: Subsystem or system experiments to quantify the maturity (risk and cost of FSED) of emerging technology; "test marketing" experiments; fenced funding for this purpose.

The Task Force assessed that the university research base for defense preparedness is in need of upgrading in faculty, equipment, facilities, and support. It is a problem broader than DoD, but DoD has a specific interest and responsibility. A number of recommendations were made in this area.

In addressing the above questions we found that the status of DoD's laboratory system and the function of DARPA were frequently a factor. There was unanimous expression of the need for in-house laboratories, but great fear that their prospects for improvement are bleak. It was also felt that DARPA's technology base programs have exceeded the capabilities of its staff to manage and that there is no comprehensive coordination of its programs with Service programs nor is there adequate dissemination of results. A number of recommendations were also made to address these problems.

The Task Force members are gratified with the positive response of DoD to the findings and with the actions that are currently under investigation by DoD to implement the recommendations. It is evident that we have tackled a sensitive topic at a critical time. I would like to take this opportunity to express my appreciation for the dedication and contribution of all of the Task Force members.

Sincerely

George H. Heilmeier

George H. Heilmeier

cc: E.G. Fubini
(w/o attachment)

IMPLEMENTATION PLAN

SUBJECT AREA: TECHNOLOGY

Recommendations

1. The ASD(R&T) formulate vertically integrated technology base programs with fenced funding, similar to VHSIC in the following areas: machine intelligence; advanced software/algorithm technology; high power microwave technology; advanced materials (rapid solidification technology, advanced composites) and computer aided training via personal electronics.

   Responsible Office: DUSD(R&AT)

2. The USDRE direct the military departments and DARPA to use the investment strategy catechism in all future technology base planning and POM guidance.

   Responsible Office: DUSD(R&AT)

3. The USDRE allocate resources to the Services and all levels of the technology base on a consistent scenario oriented basis. Recognize organizational excellence by evaluation of their matching of resources/priorities/strategies to the scenarios.

   Responsible Office: ASD(R&T)

4. The ASD(R&T) adopt a technology prioritization and investment strategy approach based on the figure of merit used in this study.

   Responsible Office: DUSD(R&AT)

5. The ASD(R&T) increase funding in the following areas: (1) machine intelligence; (2) advanced software/fast algorithms; (3) short wavelength lasers; (4) hardening of advanced electronics; (5) microprocessor-based personal training aids; and (6) fault tolerant/fail safe (self-policing) electronics.

   Responsible Office: DUSD(R&AT)

6. USDRE review general areas of activity suitable for deemphasis: duplication with NASA; over expansion of the DARPA program (i.e., (1) forward swept wing, (2) VLSI, (3) fiber optics); nonproductive duplication of the generic technology base by the three Services; and in-house execution of the basic research program (6.1).

   Responsible Office: ASD(R&T)

SUBJECT AREA: TRANSITION

Recommendations

1. Create an advanced projects agency; to develop subsystem or system experiments to quantify the maturity (risk and cost of FSED) of emerging technology; to conduct "test marketing" experiments; and to be populated by personnel in the Services.

   Responsible Office: USDRE

2. The USDRE require technology insertion plans and not as an afterthought.

   Responsible Office: DUSD(R&AT)

SUBJECT AREA: UNIVERSITY

Recommendations

1. The USDRE direct the Services to increase 6.1 basic research performed by universities by 25% in real growth over the next three years but be selective.

   Responsible Office: DUSD(R&AT)

2. The USDRE direct the DAR Committee to revise current procurement policies and regulations to allow: additional IR&D - 0.5% over present ceiling - for industry support of university R&D; treatment of university indirect costs similar to that used by U.S. Dept. of Health and Human Services (HHS); simplified research procurement from universities.

   Responsible Office: DUSD(AM)

3. The USDRE establish with the universities an accommodation and basis for the implementation of current export controls on information relating to munitions list technologies.

   Responsible Office: DUSD(IPT)

4. The ASD(R&T) direct the Services to create a DoD thrust to upgrade equipment in universities. Focus on equipment that can impact the technology thrusts requiring university research of highest DoD leverage (software, design automation, machine intelligence, etc.); the upgrading of computer resources is the highest priority based on this algorithm; and DoD should support NSF efforts to upgrade, generally, equipment in universities.

   Responsible Office: DUSD(R&AT)

SUBJECT AREA: GENERAL (Laboratory/DARPA)

Recommendations

1. To help the hiring and retention of the skills necessary for a viable laboratory structure, USDRE direct that the highly exciting and effective personnel experiment presently being conducted at NOSC and NWC be implemented for DoD Laboratories. The most exciting features of this experiment are: (1) greater latitude in job classification; (2) reduces paperwork; (3) makes performance the foremost criteria for salary increases, retention, promotion, etc.; and (4) flexibility/faster decisions.

   Responsible Office: DUSD(R&AT)

2. USDRE designate lead laboratories in generic technology base areas. Candidates include: (1) space systems related technology (components, hardening, etc.); (2) airborne radar technology; (3) airborne electronic warfare technology; (4) electron devices; and (5) infrared technology.

   Responsible Office: DUSD(R&AT)

3. USDRE authorize the Services to each establish 100 graduate fellowships per year in areas of interest to DoD: $20K/year (part to the university); competitive - awarded by Congressmen; and must work one year in DoD Laboratories for each year of fellowship support.

   Responsible Office: DUSD(R&AT)

4. The ASD(R&T) establish a mechanism to ensure coordination of system technology base programs (such as BMDATC) with the rest of the DoD technology base activity. Insure that system requirements are included in the development of the technology base investment strategy.

   Responsible Office: DUSD(R&AT)

5. USDRE direct the Services to review DARPA programs over $30M for potential future military applications, operational needs and transition plans.

   Responsible Office: ASD(R&T)

DEFENSE SCIENCE BOARD SUMMER STUDY
ON TECHNOLOGY BASE

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

APPENDICES

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The maintenance of a lead over potential adversaries in critical military technologies is a major factor in U.S. national defense. The U.S. has been able to offset the numerically superior forces of the Soviet Union with a highly leveraged qualitative arms superiority emanating from technology achievements derived from its industry, government laboratories, and academic institutions. The lead over the U.S.S.R. however, is rapidly eroding for a variety of reasons:

- DoD funding of R&D in terms of real dollars is declining;
- the U.S. is in the process of losing its competitive edge in many technology areas;
- the academic community is faced with problems which may result in an inability to provide a robust core of scientists and engineers to meet U.S. defense needs.

In the Soviet Union, the trend is exactly the opposite. They are producing several times the number of engineers per year as the U.S. and are training a whole generation of technologically literate people with a general education curriculum which is oriented toward science and technology. This trend can have a profound influence on the relative technology base in each country.

Concern for the health of the U.S. defense technology base, within and outside the government, motivated the Undersecretary of Defense for Research and Engineering to convene a Defense Science Board (DSB) Summer Study on Technology Base. The study addressed the following and related questions:

1. What technologies are critical to future (1990-2000) defense capabilities? How are these technologies identified? Are the Soviets gaining ground? Is the investment in the Technology Base of less than 2% of the total defense budget adequate?

2. Is the process of transition from technology base to weapon systems adequate?

3. Are the universities responsive to national security requirements?

4. Are the DoD relationships with the basic research community, creative individuals, and small innovative firms adequate?

5. Are the available scientific and engineering personnel resources adequate to meet the requirements of the defense technology (commercial or government)?

"Order of Magnitude" Technologies

After reviewing the technology base planning strategies employed by the Services and DARPA, it was found that there was no consistent, DoD-wide linkage between investment strategies and the requirements of future combat. To answer the questions posed above, the DSB panel was required to adopt its own structured approach to technology assessment and technology base planning which can be characterized as follows:

- Scenario projection - determine or project what the possible natures of warfare will be in the post-1990 environment in air, land, sea, and space.

- Systems and operational concepts - determine what will be required to meet the demands of these scenarios and the implied threat.

- Identify technologies - determine what impact new and innovative technology will have on systems projected for the future.

- Rank technologies - develop criteria for ranking technology in order of priority.

- Compare the technology list with the DoD resource allocation.

- Determine the requisite technology base investment strategy.

In the course of applying this scenario-based planning approach to the current DoD technology base program, the panel took into account all of the key elements of a comprehensive investment strategy for technology development, the "catechism":

- What is it? What is this effort trying to accomplish? (defining the technology sufficiently well to discriminate it from other similar technologies)

- Why is it important? Assuming success, what difference can it make to the user or in a mission area context? (taking into account the nature and limitation for current practice)

- What is the current status? What is the DoD program? What should it be? What is new about the proposed effort and why will this approach be successful?

- How long will it take? How much will it cost? What are the measures of success?

The panel recommends that the USDRE direct the Services and DARPA to incorporate such an approach in all future technology base planning and in POM guidance so that technologies funded through the allocation process would be more explicitly and consistently related to future operational needs.

In its identification and analysis of the "order of magnitude" technologies, the DSB panel attempted to balance opportunity with risk by means of a Figure of Merit (FOM) (see Chapter II for more details).

The panel also recommends that ASD(R&T) adopt the "Figure of Merit" technique or its equivalent as a basis for prioritizing technology. From this assessment the panel selected 17 technologies as being the most important for vigorous pursuit within DoD:

- Very High Speed Integrated Circuits
- Stealth
- Advanced Software/Algorithm Development*+
- Microprocessor-Based Personal Learning Aids*+
- Fail-Soft/Fault Tolerant Electronics*
- Rapid Solidification Technology+
- Machine Intelligence*+
- Supercomputers*
- Advanced Composites+
- High Density Monolithic Focal Plane Arrays
- Radiation Hardened Advanced Electronics*
- Space Nuclear Power*
- High Power Microwave Generators*+
- Large Space Structures*
- Optoelectronics
- Space Based Radar
- Short Wavelength Lasers*

Based on a comparison of the above list of technologies with the current DoD investment, a number of technologies were identified for funding increases. These technologies are noted with an asterisk(*). It should be noted that the vast majority of the "order-of-magnitude" technologies lie in the electronics area. Currently, the electronics area commands a relatively low percentage of the total budget. There is a need to reorder funding priorities within the Technology Base to correct this imbalance. The panel also felt that there are deficiencies in the way DoD has managed the technology investment for certain of these technologies. These programs could benefit from a vertically integrated program structure similar to the VHSIC Program. (See items above marked with (+). Key elements of a vertically integrated program are:

- Centralized management and coordination of the total Tri-Service program with fenced funding to ensure accountability.

- The inclusion under one industrial organization of all aspects of a technology's development and transition into military systems (e.g., processes, design, materials).

- Continuity of the industrial team(s) from early technology development through transition to system applications.

Although no effort was made to recommend specific programs which should be deleted, several categories of activity were highlighted for deemphasis:

- Areas of duplication with NASA (e.g., remote sensing, propulsion)

- Overexpansion of DARPA programs into areas which overlap with other major DoD/Service programs (e.g., forward swept wing, VLSI, fiber optics)

- Nonproductive duplication of the generic technology base by the three Services

- In-house execution of the basic research program (6.1).

The overall level of funding (2% of the DoD budget) was judged to be adequate, if effectively organized and managed. The panel has concluded that this ideal cannot be achieved unless the decision making and allocation process within DoD is restructured to reflect the planning methodology outlined in this report.

Technology Transition

A number of barriers were identified which inhibit the successful transition of technology into systems. There is little incentive to exploit or respond to new technology owing to:

- Discontinuity of funding, indecision, and the short term orientation of many key decision makers

- The organizational and spatial separation of technology base and systems people

- Very little emphasis on technology demonstrations which accurately portray risk reduction, payoff, and cost factors for later stage production

- Very little emphasis on "test marketing."

A champion on the operational user side or user support is often not present.

In order to better focus DoD resources on the transition issue the panel recommends that the USDRE direct the creation of an advanced projects agency staffed by Service personnel:

1. to develop subsystem or system experiments to quantify the maturity (risk and cost of FSED) of emerging technology,

2. to conduct "test marketing" experiments, and

3. to fence the funding for the above described experiments.

However, even if the agency is not formed, it is very important that the Services apportion and fence a larger 6.3A element for conducting these experiments.

The panel also found that the DoD does not plan well for successful technology transition throughout the life of a system. Such plans are often injected only as an afterthought. It recommended that the USDRE require technology insertion plans as a basic and fundamental part of program planning.

University Connection

The university research base related to defense preparedness is in need of upgrading in faculty, equipment, facilities, and support. If the current trends persist, the universities may no longer be able to provide for the training of "world-class" technical talent or performance of "world-class" scientific research in areas key to our military and economical security. The key issues identified are:

- Obsolescence of equipment and facilities
- Shortages of faculty, especially in some engineering fields and computer science
- Shortages in disciplines outside of science and technology (e.g., foreign lanugages critical to communication and intelligence)
- The increasing percentage of foreign graduate students in science and engineering departments of many major universities
- Certain DoD procurement policies

The DoD and the country face a crisis in the availability of technical personnel. It is a problem broader than DoD, but DoD has a specific interest and responsibility.

A number of specific recommendations were made with regard to these problems:

1. The USDRE direct the services to increase 6.1 basic research performed by universities by 25% in real growth over the next three years.

2. USDRE authorize each of the services to award 100 S&E graduate fellowships annually.

   - In areas of DoD interest - similar to those of the DoD laboratories
   - $20K/year to continue until completion of degree but not to exceed 3 years (part to students and part to university)
   - Competitive -- awarded by Congressmen
   - Must work one year in DoD lab for each year of fellowship support granted

3. The USDRE direct the DAR Committee to revise current procurement policies and regulations to allow:

   - Additional IR&D -- 0.5% against negotiated base over present ceiling -- for industry support of university R&D

- Treatment of university indirect costs similar to that used by U.S. Dept of Health and Human Services (HHS)

- Simplification of research procurement from universities

4. The USDRE establish with the universities an accommodation and basis for the implementation of current export controls on information relating to munitions list technologies.

5. The ASD(R&T) direct the services to create a DoD thrust via the OSR's to upgrade equipment in universities. This focus should be on equipment that can impact university research of highest DoD leverage (software, design automation, machine intelligence, etc.)

   - The upgrading of computer resources is the highest priority based on this algorithm.

   - Generally, DoD should support NSF efforts to upgrade equipment in universities.

The theme of the above recommendations is to increase the level of investment for 6.1 basic research performed in universities by a total of 25% in real growth over the next three years. A recommendation was made for an in-depth study in order to answer the House Armed Services Committee's questions with regard to "University Responsiveness to National Security Requirements."

DoD Laboratories and DARPA

In addressing the above questions the status of DoD's laboratory system and the function of DARPA were frequently a factor. There was unanimous expression of the need for in-house laboratories, but great fear that their prospects for improvement are poor:

- There is an impending crisis in personnel and facilities in the DoD laboratories that will seriously degrade the defense posture in a very few years.

- The present DoD laboratory base is weak, fragmented, and duplicative in key areas (e.g., computer science, machine intelligence, software, VLSI, and signal processing).

- Too often the laboratories conduct R&D in areas of their expertise instead of in areas of the greatest military need.

- In the case of DARPA:

  - The growth in the DARPA technology base program has greatly exceeded the capability of the staff to properly execute the program

- There appears to be no comprehensive filtering of DARPA programs versus on-going Service efforts and the DARPA results are not widely disseminated and therefore not sufficiently critiqued.

Based on these findings, the following recommendations were made:

- To help the hiring and retention of the skills necessary for a viable laboratory structure, USDRE direct that the highly exciting and effective personnel experiment being conducted at NOSC and NWC or its equivalent be implemented for DoD laboratories.

- USDRE, in conjunction with Service technology base managers, designate lead laboratories in generic technology base areas within each Service. Candidate technology areas include: Space systems related technology (components, hardening, etc.); airborne radar technology; airborne electronic warfare technology; electron devices; and infrared technology.

- USDRE direct that Services review DARPA programs over $30M (total program costs -- not annual) from the point of view of potential future military applications, operational needs, and transition plans, <u>and</u> establish a mechanism to ensure coordination of system technology base programs (such as BMDATC and ABRES) with the rest of the DoD technology base activity to ensure that multiple system requirements are included in the development of the technology base investment strategy.

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

A. THE DECLINE OF THE U.S. TECHNOLOGY BASE

The technology base is a critical factor in national defense, particularly in the present context. In recent years, the U.S. has been able in most cases to offset the numerically superior forces of the Soviet Union with a highly leveraged qualitative arms superiority. The U.S. has been able to achieve this leverage because it possesses a superior technology base in U.S. industry, in governmental laboratories, and in our academic institutions.

The U.S. technology lead over the U.S.S.R., however, is eroding in critical military technologies and this decline is being felt in many areas of technology (see Figure I-1 for recent trends). DoD funding of research and development in terms of real dollars has declined in advanced technology areas. U.S. industry has lost its competitive edge in many areas of high technology as many U.S. corporations pursue strategies of short term gain at the expense of long term growth. Foreign firms are investing greater percentages of profits in R&D, in new factories and other capital equipment, and in advanced manufacturing methods.

For a variety of reasons, the academic community during the 1970's has not provided a robust basic core of scientific and engineering talent to meet America's defense needs. Institutions at both the secondary and university levels are retreating from the commitment to science and technology developed during the post-Sputnik era. Weaker curricula are resident in many schools and students in greater numbers are avoiding the hard sciences. Although engineering enrollments are now increasing, only recently have doctoral enrollments returned to the levels of the early 1970's. Moreover, our increasing fraction of science and engineering graduate students are foreign, the fraction approaching 50% in selected fields.

In the Soviet Union, the trend is exactly the opposite (see Figure I-2). They are producing several times the number of engineers per year as the U.S. and are training a whole generation of technologically literate people with a general education curriculum which is oriented toward science and technology. This trend can have a profound influence on the relative technology base in each country.

Even granting the historical inefficiencies in the Soviet system in its economic and industrial output, their push toward technology equivalence with the West will have important military effects. It is even being aided by a wholesale technology transfer from the West through licensing agreements to Bloc countries, training of foreign nationals in universities, and a continuing flow of current and militarily relevant information transferred through international scientific meetings and the open technical literature.

It would be presumptuous to assume that the technology gap will continue to exist (assuming that it exists today) and naive to expect that the U.S.

FIGURE I-1

RELATIVE U.S./USSR STANDING IN THE 20 MOST IMPORTANT BASIC TECHNOLOGY AREAS

BASIC TECHNOLOGIES	U.S. SUPERIOR	U.S.-USSR EQUAL	USSR SUPERIOR
1. Aerodynamics/Fluid Dynamics		X	
2. Automated Control	X		
3. Conventional Warhead (including Chemical Explosives)			X
4. Computer	X		
5. Directed Energy		X	
6. Electro-optical Sensor (including IR)	X→		
7. Guidance and Navigation	X→		
8. Microelectronic Materials and Integrated Circuit Manufacture	X		
9. Nuclear Warhead		X	
10. Optics	X→		
11. Power Sources (Mobile)			X
12. Production/Manufacturing	X		
13. Propulsion (Aerospace)	X→		
14. Radar Sensor	X→		
15. Signal Processing	X→		
16. Software	X		
17. Stealth (Signature Reduction Technology)	X		
18. Structural Materials (light weight, high strength)		←X	
19. Submarine Detection (including Silencing)	X→		
20. Telecommunications	X		

*1. The list in aggregate was selected with the objective of providing a valid base for comparing *overall* U.S. and USSR *basic* technology. The technologies were specifically not chosen to compare technology level in currently deployed military systems. The list is in alphabetical order.

2. The technologies selected have the potential for significantly changing the military balance in the next 10 to 20 years. The technologies are not static; they are improving or have the potential for significant improvements.

3. The arrows denote that the relative technology level is changing significantly in the direction indicated.

4. The judgments represent averages within each basic technology area.

FIGURE I-2

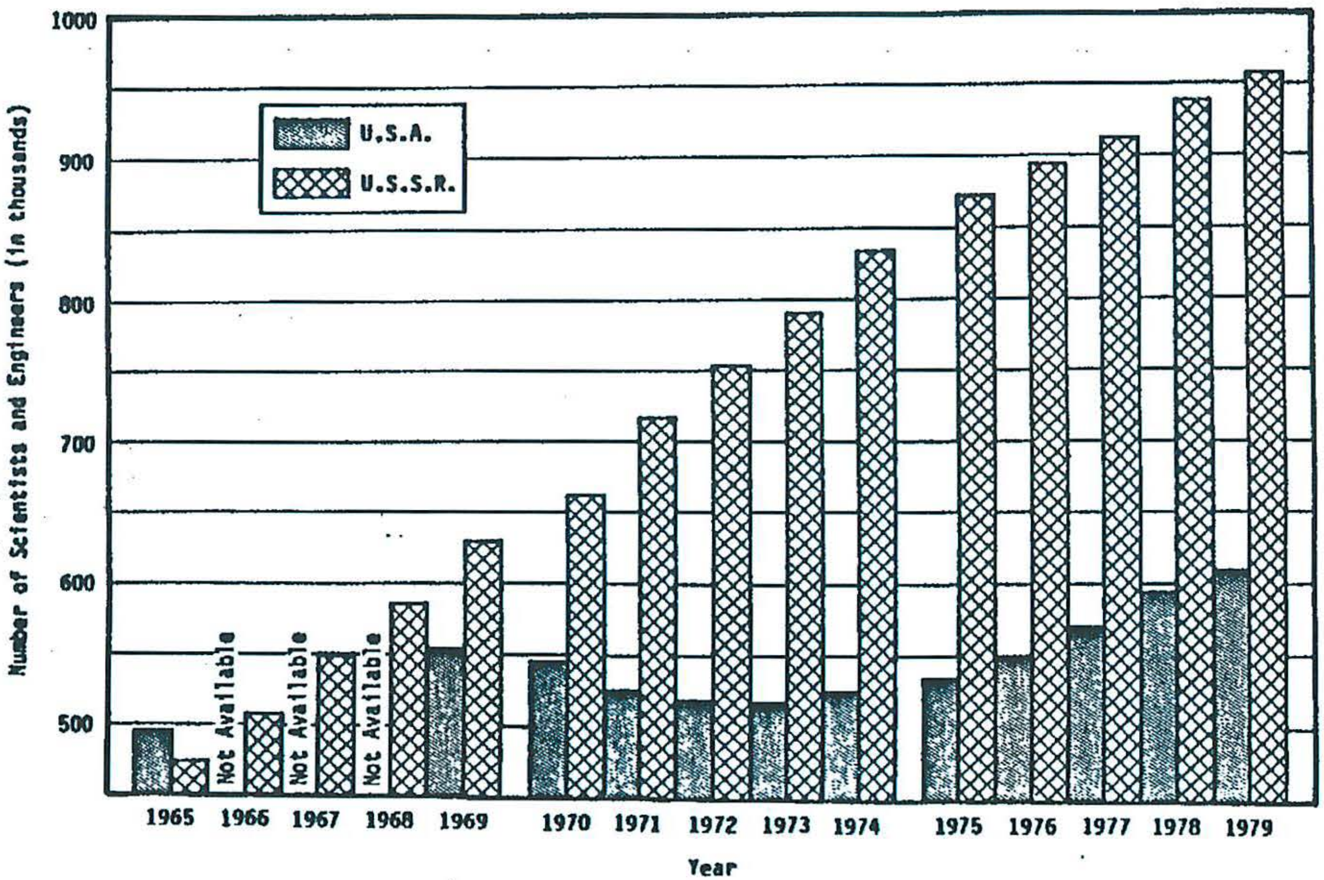


Figure . Scientists and Engineers Employed in Research and Development in the United States and the U.S.S.R.: 1965 to 1979

Source . Department of Commerce

qualitative advantage will persist given the present trend. The U.S. edge in key technologies can be lost and, in fact, will be lost without attention to:

1. the health of the continuing technology base within the in-house R&D community, the academic community, and industry;

2. the transition of innovative technology into credible and deployable military systems; and

3. the evolution of creative military operational concepts which exploit U.S. strengths and/or Soviet Union vulnerabilities.

B. TASKS

1. Accordingly, on 2 July 1981, the Under Secretary of Defense for Research and Engineering (USDR&E) chartered the Defense Science Board (DSB) to undertake a Summer Study to assess the health of the U.S. national defense technology base, within and outside the government. Specific questions to be addressed by the DSB were:

- What technologies are critical to future (1990-2000) defense capability? What are those technologies that would contribute to roughly an order of magnitude improvement in system performance, cost, etc.? How are these technologies identified? Are the Soviets gaining ground? Is the investment in the technology base of less than 2% of the total defense budget adequate? If not, what is a reasonable level of expenditure and what should be the management and investment strategy within the technology base?

- Is the process of transition from technology base to weapon systems adequate? If not, what changes are needed to accelerate the process of transition?

- Are the universities responsive to national security requirements? If not, what actions should be taken to improve the responsiveness of universities?

- Is the DoD relationship with the basic research community, creative individuals and small innovative firms adequate? If not, what changes should be made to improve the DoD utilization of these resources?

- Are the scientific/engineering personnel resources adequate to meet the requirements of defense technology (commercial or government)? What actions should be taken to eliminate critical personnel shortages?

Priority was assigned to the first two questions.

2. The DSB held two preliminary meetings in Washington, D.C., during June and July 1981, and then met during the period 2-14 August 1981 at the Naval Ocean Systems Center, San Diego, California. The Panel was chaired by Dr. George H. Heilmeier, Vice President, Corporate Research, Development and Engineering, Texas Instruments, Inc., and included as members science and engineering leaders from industry, universities, defense agencies and

the independent research community. The Board's charter is contained in Appendix A. Figure I-3 lists the total membership of the Technology Base Panel.

C. PERSPECTIVE - NO ILLUSIONS

Over the last decade, there have been literally dozens of reports, study panels, and "Blue Ribbon" committees dedicated either directly or indirectly to the problem of the technology base. Generally speaking, the recommendations made in a majority of these efforts have largely been ignored by DoD institutionally. Part of this may be the result of the "blue sky" nature of some of the recommendations. But a more serious problem exists when the institution fails to recognize and implement recommendations which are on target. (See Appendix B for a review of past studies.)

The DSB panel aimed at recommendations which are practical and which can be implemented within the DoD. Even though they may require a strong and deliberate effort, and are aimed at breaking strong historical patterns, we believe they are in the realm of the possible. We also are conscious of the fact that a panel such as this, meeting for only a short time, cannot hope to solve problems of a detailed nature and, therefore, focuses on broad issues and takes a broad approach to DoD-wide problems. It is noted, however, that a panel such as this, the members of which have long associations with technology assessment and planning, lends perspective and objectivity to the process of DoD self-examination.

Those few panels which in the past have made a major impact have done so because the time was right for change. It is believed that such is the case with technology base planning at this time, since the current shortfalls are now reaching dangerous proportions.

D. CAVEATS

1. For purposes of this study, the DoD technology base was defined as the total research (6.1) and exploratory development (6.2) effort, plus a portion of the advanced development (6.3A) program. Collectively, these elements represent an FY 1981 budget of $3.2 billion, supporting basic research, exploratory development, and some advanced development performed by universities, industry, DoD laboratories, and Federal Contract Research Centers (FCRC).

2. The DSB panel recognized the lack of methodology, priority, or relationship between desired future operational capabilities and technology, and, therefore, consciously concentrated on technologies which could have an "order of magnitude" impact on military capability in some critical attribute (performance, reliability, simplicity, etc.). This focus was selected in order to ensure that they receive adequate support and focus in the years to come. However, technologies which can make an "order of magnitude" difference are not the only ones worthy of support. Often, systems derived from less exotic technology can outperform systems of a more advanced technology when the support, training, and maintenance demanded by the latter have been allowed to lag and are, therefore, insufficient for proper deployment and operation.

FIGURE I-3

MEMBERSHIP
DSB SUMMER STUDY ON TECHNOLOGY BASE

Chairman	Present Position
Dr. George H. Heilmeier	Vice Pres., Corp RD&E, Texas Instruments, Inc.
Vice Chairman	
Mr. Donald J. Looft	Vice Pres. & General Mgr., E/O Div, Magnavox
Executive Secretary	
Dr. Samuel A. Musa	Staff Specialist for EW & Target Acquisition, OUSDRE
Members	
Mr. Richard Alberts	Mgr., R&D Policy & Plans, Research Triangle Inst.
Dr. Ivan L. Bennett, Jr.	Exec. VP Health Affairs, NYU, Provost & Dean, NY Med. Cen.
Dr. Arden L. Bement	Vice Pres., Tech. Resources TRW, Inc.
Dr. Robert S. Cooper	Director, DARPA; ASD (Res. & Tech.) (Designee)
Dr. Edward T. Gerry	Pres., W.J. Schafer Assoc.
Dr. Norman Hackerman	Pres., Rice University
Dr. Bernard A. Kulp	Ch. Scientist, Dir. of Labs, AFSC
Dr. Reuven Leopold	Chmn. of Board, NKF Engrg., Inc.
Mr. Charles H. Mckinley	VP., Msl. Dev. Engrg., Vought Corp.
MGen Emmett Paige, Jr., USA	Commander, U.S. Army Electronics R&D Command
Dr. Herbert Rabin	DASN (Res. Applied Space Tech.)
Dr. Sayre Stevens	Principal, Booz Allen & Hamilton
Dr. Gerald F. Tape	Spec. Asst. to President, AUI
BGen. Brien D. Ward, USAF	Director of Labs, AFSC
Major Assistance	
Mr. Bradford L. Smith, Jr., Dr. Patrick P. McDermott, and Ms. Jo Marie Diamond	B-K Dynamics, Inc.

3. An in-depth treatment of any one area is beyond the scope of this study. Because of the duration of the study, it was often necessary to make qualitative assertions about technology since accurate quantitative analyses were not available.

4. Outside of those areas indicated in Figure I-1, there was no attempt made by the DSB panel to assess relative U.S.-U.S.S.R. technology levels in the "order of magnitude" technologies. This lead/lag assessment is an important element of the defense planning process, however, in view of the U.S. dependence on maintaining a qualitative arms superiority as an offset to Soviet quantitative superiority in certain technical areas.

Although it could be improved with more input from the R&D community, the technology National Intelligence Estimate (NIE) (Figure I-1) is becoming an important tool for assessing the long term U.S./U.S.S.R. military balance. Technology lead does not translate directly into military superiority since there is a significant lag in the introduction of new technology into systems. If the Soviets accelerate this transition into systems, they may be able to close the qualitative gap which now exists in many technology areas.

Nonetheless, this concept of lead/lag based on a technology NIE is an important consideration for DoD long range planning. The process could be improved considerably in the NIE or a parallel effort attempted to interpret the military significance of the assessed lead/lag and/or incorporated some measure of operational impact, a sort of "technology threshold" for assessing operational significance.

E. ORGANIZATION OF THE REPORT

1. To facilitate review, the report of the Technology Base Summer Study has been organized into a series of chapters which, generally, parallel the major areas of investigation identified in the DSB initiating charter. Specifically:

- Chapter II addresses the range of issues associated with the identification of "order of magnitude" technologies.
- Chapter III evaluates the total technology base investment.
- Chapter IV focuses on the process of transition from technology.
- Chapter V deals with the question of the responsiveness of universities to national security requirements.
- Chapter VI treats the issues associated with the DoD laboratories and the Defense Advanced Research Projects Agency (DARPA).
- Chapter VII provides a composite summary of DSB findings and recommendations.

2. The methodology(ies) applied within each section are explained and documented, as appropriate, in the body of the report and, where necessary, additional explanation is provided in an appendix.

CHAPTER II

IDENTIFICATION OF THE "ORDER OF MAGNITUDE" TECHNOLOGIES

CHAPTER II

IDENTIFICATION OF THE "ORDER OF MAGNITUDE" TECHNOLOGIES

A. METHODOLOGY

It was the intent of those involved in the study to generate and test a methodology for technology base planning to be used as a model for OSD and the military departments. This action was necessitated by the fact that there is no uniform, structured methodology or process within DoD for identifying or prioritizing critical technology areas. The approach adopted can be characterized as follows:

- Scenario projection - determine or project what will be the nature of warfare in the post-1990's environment in air, land, sea and space; define the mission requirements such warfare will place on future military systems.

- Systems and operational concepts - determine what system functions will be required to meet the demands of these scenarios and the implied threat.

- Identify technologies - determine what impact new and innovative technology will have on systems projected for the future.

- Rank technologies - develop criteria for ranking technology in order of priority.

- Compare technology list with DoD resource allocation - match, by line item, the dollars being spent for technology development with list of technologies considered crucial in the future context; identify which of the top ranked technologies are underinvested; look for areas of overinvestment.

- Determine technology base investment strategy.

This chapter is organized in a manner which illustrates the methodology outlined above including: 1) the delineation of the post-1990's scenarios based on a synthesis of Service long range plans; 2) description of the technical requirements derived from such scenarios, especially those which permeate the future scenarios; 3) identification and ranking of technologies with an "order of magnitude" impact on the defined future system requirements; and 4) definition of investment strategies for technology development of the top technologies including an evaluation of the current technology base programs in these technologies.

B. POST 1990s SCENARIOS

These factors are described in detailed scenario descriptions and are contained in the classified version of this report. Scenarios were broad in scope dealing with projected functional attributes of land warfare, air warfare, naval warfare, and strategic and space warfare. Based upon the above definition of the 1990's environment, the panel members performed an assessment of the critical technical requirements needed to achieve success in each specified warfare scenario. The results of this assessment are summarized in Table II-1. In the course of defining these technical requirements, a series of "integrating factors" were identified which permeate the future scenarios, representing needs which are pervasive to a wide range of critical future operations. These factors are:

- Sustained Operations
- Continuous Threat Location/Track
- Real-Time Information Management
- Counter Threat Target Acquisition
- Integrate "Eyeball and Trigger"
- Secure, Jam-Resistant, Mobile Communications
- Dispersed, Small Units
- Transparent Complexity
- Equipment Availability/Reliability
- Operations in Extreme Environments.

Each of these factors is described in more detail in the classified version of this report.

C. IDENTIFICATION AND RANKING OF TECHNOLOGIES WITH AN "ORDER OF MAGNITUDE" IMPACT ON FUTURE CAPABILITY

As mentioned earlier in this report, this DSB summer study focused exclusively on technologies which can make an order of magnitude difference in terms of deployable operational capability. This section of the report delineates the summary assessment of these technologies and develops a rank ordering for the most critical technologies.

In its identification and analysis of the "order of magnitude" technologies, the DSB panel attempted to isolate which technologies would be important for success in the scenarios outlined earlier and then to evaluate the relative contribution of each. In order to accomplish this, the DSB panel developed certain criteria for assessing "opportunity" and "risk."

TABLE II-1

Scenario Driven Technical Requirements

AIR WARFARE

STAND-OFF, SANITIZE OR STAY AT HOME
INCREASED ROLE OF STAND-OFF WEAPONS

-- Long-range air or missile delivery of guided, non-nuclear, wide area munitions (with TGSMs)
-- Longer range defenses against weapon carriers
-- Air defense area suppression
-- Stealth

DISPERSED BASE OPERATIONS

-- Mobile ground-support operations
-- Hardened air control facilities
-- Use of lower-grade airfields

PREMIUM ON STEALTH

-- Stealth technology
-- New concepts of air defense - new sensing phenomena
-- Avoidance of surprise by stealth

NEAR REAL TIME (NRT) INTEGRATION OF TARGET ACQUISITION AND STRIKE

-- Autonomous on-board processing of signal data
-- Very high precision location reference, such as (GPS)
-- TGSMs
-- NRT data fusion and strike preparation

INCREASED TACTICAL USE

-- Space-based surveillance sensors with autonomous processing
-- Survivable, unjammable, continuously available location reference
-- Survivability of sensor systems in face of attack and nuclear environment
-- ECM-resistant, survivable, wide-band COMSATS
-- Space-based jammers against ground and space targets
-- Non-nuclear anti-satellite weapons

RICH ECM ENVIRONMENT

-- Operation of RF systems in high energy, broad spectrum noise environment
-- Concealment of ECCM approaches including agility
-- Simultaneous ECM and SIGINT exploitation
-- Targeting ECM sources
-- Low-cost EHF equipment
-- Very high-power, mobile equipment

NAVAL WARFARE

CRUISE MISSILES VS. MANNED NAVAL AIR FOR STRIKE

-- ASCM defense - detection and neutralization or kill
-- Platform signature reduction or replication
-- Denial of targeting data for long-range systems
-- NRT targeting and SLCM strike preparation

WORLDWIDE REAL TIME TRACKING AND TARGETING OF MAJOR SURFACE COMBATANTS

-- Spoofing or jamming of space-based surveillance systems

ASW - LONG-RANGE LOCALIZATION

-- Signature suppression
-- ASW link disruption
-- ASW weapons avoidance
-- Integration of localization and strikes
-- Long-range ASW strike

TACTICAL USE OF SPACE FOR NAVAL WARFARE

-- Space-based surveillance of aerodynamic threats
-- Integration of threat detection and defensive response
-- Surveillance detection and response
-- Space-based and space-targeted ECM

VERY LONG-RANGE, LONG-ENDURANCE AIR SURVEILLANCE ORGANIC TO THE TACTICAL COMMANDER

-- Platform availability is the key issue
-- Sensors, processing and integrating must evolve from the tech base

LAND WARFARE

CONTINUOUS OPERATIONS

-- Sustaining human performance
-- Night-time operations
-- Environmental protection in areas denied by CW and nuclear effects

IMPRACTICALITY OF TROOP CONCENTRATION

-- Integration of small unit operations with survivable command and control
-- Disrupting dispersed enemy command and control
-- Unit agility required for sustained fire power application
-- Decentralization and mobility of currently nonmobile fixed facilities; e.g., nuclear weapon storage, maintenance, etc.

MOBILITY, AGILITY, AND FIREPOWER

-- Real-time detection and response to fleeting sightings of concentrations
-- Rapid mobility of high firepower systems
-- Defensive systems to delay mobile ground forces
-- Very low-leak rate air defense of small high-value targets

SMALL UNIT ACTIONS

-- Integrating of small unit operations, C^3
-- Agility and rapid mobility
-- Data base availability
-- Decentralized processing of complex data
-- ECCM
-- Integral defenses

FINDING THE ENEMY/SEEING DEEP

-- Near continuous surveillance of selected areas
-- Rapid search of large areas
-- Fusion of data for intelligence and weapons systems
-- Cover and deception
-- Rapid response in signal frequency and pulse form

INTEGRATED NUCLEAR, CW, AND ECM OPERATIONS

-- Sustained operations in areas denied by nuclear and CW weapons
-- CW detection and defense, including low-level, slow-acting agents
-- Noise-filled RF environment
-- Detection/concealment of moves to counter first use of nuclear weapons
-- Simultaneous ECM and SIGINT exploitation
-- Accelerated nuclear/CW procedures

BATTLEFIELD EXPANSION IN DEPTH

-- Elimination of critical fixed facilities and deployment nodes
-- Super-accurate non-nuclear weapon with tailored effects
-- Very low-leak rate ATBM, air defenses and targets of limited extent
-- New concepts for resupply terminals, i.e., ports, air/rail supply nodes, etc.

STRATEGIC AND SPACE WARFARE

SUSTAINED STRATEGIC OPERATIONS

-- Operation in high radiation environment
-- Dispersed forces, facilities, C^3

AGGRESSIVE DEVELOPMENT OF EFFECTIVE BMD

-- Space-based directed energy (high risk/high payoff)
-- Layered point defense (nuclear kill and non-nuclear kill)
-- Surveillance/targeting to counter penetration aids

SPACE AS A WARFARE DOMAIN

-- Combination of interceptors and directed energy weapons
-- Need for satellite point defense
-- Space-launched antiground conventional weapons may evolve

OPPORTUNITIES

Impact or Opportunity

1. Mission Value
2. Technology Impact on Mission/System
3. Pervasiveness
4. Nature of Impact
5. Leverage (Exploits U.S.-U.S.S.R. Asymmetry)
6. Simplicity
7. Cost
8. Existence of Alternatives
9. Duration of Impact

RISKS

Technical Risks

1. Maturity of Technology
2. Technology Base
3. Innovation Potential

System/Operational Concept Risks

1. Mission/System Related Risks
2. Political Bureaucratic Environment
3. Level of Operational/Support Impact

R&D Costs

1. Manufacturing Base
2. Uniqueness of Military R&D

What follows is a discussion of these criteria and a methodology for value weighting or ranking the various technologies according to a figure of merit.

Definition of Criteria

Impact or Opportunity

1. Mission Value: Technologies which support critical missions will always be assigned the highest rating. Strategic forces, for example, have historically received the highest priority in both the U.S. and U.S.S.R. Space is another area of very high mission value.

2. Technology Impact on System/Mission: Some technologies are absolutely essential for certain capabilites (e.g., nuclear power for SSBNs; large, very high speed computers for BMD). The closer a technology is to creating or sustaining the mission capability, the more "value" it contains.

3. Pervasiveness: If a technology contributes some value to a wide variety of systems or missions, it has a cumulative impact which is very high. Certainly computers and VHSIC would fall into this category.

4. Nature of Impact: If the impact of a technology is immediate then it has higher value than one which produces gradual or evolutionary change.

5. Leverage (Exploits U.S.-U.S.S.R. Asymmetry): Success in warfare often results from exploiting weakness of the adversary or the exploitation of one's own strength. Any technology which exploits asymmetries in force balance will automatically be of very high value. The timing of this impact is also crucial. Technologies which exploit such asymmetries in the near term are of greater value than those which will impact in the long term.

6. Simplicity: Simplicity adds value since it adds utility. Systems which are overly complex when used in a battlefield situation tend to be more vulnerable and unreliable. Simplicity in this context, does not imply a lack of sophistication. The modern microprocessor is a highly complex item which adds simplicity because it can be packaged in a very small volume and use little power.

7. Cost: A technology which radically lowers cost is of great military value since many aspects of warfare require the deployment of high numbers of systems. Affordability often becomes a major driver in decisions on deployment of certain operational systems.

8. Existence of Alternatives: A technology has high value if there are no alternatives. As an example, a technology which offers no alternatives is the microprocessor when used to perform very complex computations in a constrained missile guidance unit.

9. Duration of Impact: Warfare and the preparations for it are iterative processes. If one side builds a superior weapon, then the other side must be expected to respond. This response requires a certain amount of time. The length of time required for the adversary to respond becomes the "value added" for the technology.

Technical Risks

1. Maturity of Technology: Emerging technologies are inherently a high risk because of the limited experience in their application. A weapon designer will always, at some point, try to utilize a mature technology if he can afford it.

2. Technology Base: The weapon or system designer prefers to use technology which is practiced within the DoD technical community. Such technologies have less risk than those technologies which must be developed or imported.

3. Innovation Potential: An important element of risk when considering investment is the availability of "good ideas" to pursue. If industry is fully exploiting the range of available options, DoD investments may add little.

System/Operational Concept Risks

1. Mission/System Related Risk: A technology's risk can also be directly related to the newness of the system concept which it supports. If the concept is new then there is more risk, even if the technology required to support the concept is not in itself risky. There are many factors in addition to technology which must be considered when implementing a new concept.

2. Political/Bureaucratic Environment: Institutional inertia is a fact of life. If a new concept uses technology in a new way which competes with established systems, infrastructures, or international agreements, then it will entail more risk to employ.

3. Level of Operational Support: If new systems or new use of technology results in unique skill requirements, facilities, or support infrastructure, the risk of successful operational deployment is raised.

Costs

1. Manufacturing Base: If the deployment of a new technology requires the establishment of a complete manufacturing capability, the cost of advanced technologies can be capital intensive. Not only are the costs higher in this circumstance but the deployment will, in all likelihood, require a longer timetable.

2. Uniqueness of Military R&D: If technology is primarily commercial, the DoD may rely heavily on R&D already underway within commercial enterprises. If not, DoD must itself become the developer of the technology. This technology must then bear the full cost (and risk) of evolving the required know-how. Again, there is an implied risk in bearing such R&D expense.

Figure of Merit

The figure of merit developed by the DSB panel is calculated by dividing opportunity by risk. Panel members were asked to examine each technology by the above criteria and to judge whether the opportunity/risk was high, medium, or low for each criterion. This judgment was then quantified in the following manner:

High Opportunity = 9	High Risk = 9
Moderate Opportunity = 4	Moderate Risk = 4
Low Opportunity = 1	Low Risk = 1

A logarithmic spread ($9,4,1 = n^2$ where $n = 3,2,1$) was used instead of a linear spread (3,2,1) in order to sharpen and accentuate differences among the three levels, high, medium, and low. (See Appendix E for an analysis of the Figure of Merit using other weightings (3,2,1 and $27,8,1 = n^3$ where $n = 3,2,1$).

The figure of merit is determined by summing the opportunity factors and dividing by the sum of the risk factors.

$$\text{Figure of Merit} = \frac{\sum \text{Opportunities}}{\sum \text{Risks}}$$

Table II-2 shows a sample figure of merit calculation.

TABLE II-2

SAMPLE FIGURE OF MERIT CALCULATION

		HIGH (9 PTS) - GREEN	MED. (4 PTS) - YELLOW	LOW (1 PT) - RED	RATING
IMPACT ON OPPORTUNITY	1) MISSION VALUE	STRATEGIC NUCLEAR (OFFENSE AND DEFENSE); SPACE	TACTICAL NUCLEAR TACTICAL CONVENTIONAL	GENERAL SUPPORT AND LOGISTICS	9 -
	2) TECH IMPACT ON MISSION/SYSTEM	RAISON-D'ETRE - SYSTEM WOULD NOT EXIST W/O THIS PARTICULAR TECH, ORDER OF MAGNITUDE IMPROVEMENT	TECHNOLOGY SIGNIFICANTLY AFFECTS PERFORMANCE	GENERALLY AFFECTS PERFORMANCE	9
	3) PERVASIVENESS	ACROSS MANY MISSIONS AND SYSTEMS	SUPPORTS ONE MISSION OR CLASS OF SYSTEMS	SPECIFIC TO ONE OR A FEW SYSTEMS	1
	4) NATURE OF IMPACT	REVOLUTIONARY	SIGNIFICANT CHANGE	EVOLUTIONARY	9
	5) LEVERAGE (EXPLOITS US/USSR ASYMMETRY)	GIVES CAPABILITY TO REDRESS SHORT TERM IMBALANCE (E.G., CM PRESENT OR PROJECTED SYSTEM)	REDRESSES LONG TERM IMBALANCES	U.S./U.S.S.R. FORCE STRUCTURES ARE COMPATIBLE IN SIZE AND SOPHISTICATION FOR NOW AND FUTURE	4
	6) SIMPLICITY	COULD RADICALLY SIMPLIFY WEAPONS	MODERATE INFLUENCE	LITTLE IMPACT	1
	7) COST	COULD RADICALLY REDUCE COST	MODERATE INFLUENCE	LITTLE IMPACT	1
	8) EXISTENCE OF ALTERNATIVES	NO VIABLE ALTERNATIVES	BRUTE FORCE COULD CREATE AN ALTERNATIVE	ONE OR MORE EXISTS	9
	9) DURATION OF IMPACT	CM LOWER IN COST COULD EXIST IN >10 YEARS	IN <10 YEARS	IN <5 YEARS	9
				TOTAL OPPORTUNITY	52.0

		LOW (1 PT) - GREEN	MED. (4 PTS) - YELLOW	HIGH (9 PTS) - RED	RATING
TECHNICAL RISK	1) MATURITY OF TECHNOLOGY	MATURE TECHNOLOGY	STILL DEVELOPING	APPLICATION UNCERTAIN, EMERGING	4
	2) TECHNOLOGY BASE	PRINCIPAL TECHNOLOGIES ARE PRACTICED IN DoD COMMUNITY	A "GAP" EXISTS: BUILDS ON CURRENT KNOWLEDGE BASE	A "GAP" EXISTS: REQUIRES NEW KNOWLEDGE BASE	1
	3) INNOVATION POTENTIAL	DoD APPROACH PROVIDES A SIGNIFICANT PERFORMANCE ADVANTAGE	MORE EVOLUTIONARY IN NATURE	DoD $$$ ADDS LITTLE SINCE THIS IS AN AREA OF STRONG TECHNOLOGY COMPETITION	4
SYSTEMS/OPERATIONAL CONCEPT RISKS	1) MISSION/SYSTEM RELATED RISKS	SIMILAR CONCEPTS OR SYSTEMS TO CURRENT DoD	REQUIRES EXTENSIVE APPLICATION SUPPORTS NEW SYSTEMS/CONCEPT TO DoD BUT ONE WHICH IS IN EXISTENCE	SYSTEM/CONCEPT NOT IN EXISTENCE TODAY	4
	2) POLITICAL BUREAUCRATIC ENVIRONMENT	REQUIRES EXTENSION OF EXISTING SYSTEM/TREATIES/INFRASTRUCTURE	REQUIRES DISPLACEMENT OF MATURE TECH OR CREATION OF AS YET UNPERCEIVED NEEDS	DEPENDENT ON ASSETS CONTROLLED BY EXTENSIVE INFRASTRUCTURES; REQUIRES CHANGE IN ARMS CONTROL AGREEMENT	9
	3) LEVEL OF OPERATIONAL/SUPPORT IMPACT	CAN TAP AVAILABLE PERSONNEL AND/OR SUPPORT	REQUIRES SOME UNIQUE SKILLS/SUPPORT	REQUIRES SIGNIFICANT SHIFT IN PERSONNEL AND IN SUPPORT INFRASTRUCTURE	4
R&D COSTS	1) MANUFACTURING BASE	BUILDS ON AVAILABLE BASE	REQUIRES UNIQUE FACILITY	CAPITAL INTENSIVE AND REQUIRES SIGNIFICANT $$ EXPENDITURES KEY PROCESSES MUST BE DEVELOPED	4
	2) UNIQUENESS OF MILITARY R&D	PRIMARILY COMMERCIAL, DoD EXPLOITS COMMERCIAL DEVELOPMENTS	SELECTED ASPECTS OF TECHNOLOGY ARE UNIQUELY MILITARY	UNIQUELY MILITARY HIGH R&D COST TO DoD	4
SUMMARY		ORDER OF MAGNITUDE IMPACT: HIGH OPPOR./LOW RISK - MOSTLY GREEN	MIXED	IMPACT UNCLEAR	
				TOTAL RISK	34.0
				FIGURE OF MERIT	1.5

$$\frac{\Sigma\,\text{Opportunity}}{\Sigma\,\text{Risk}} = \frac{5(G) + 1(Y) + 3(R)}{1(G) + 6(Y) + 1(R)}$$

$$= \frac{5(9) + 1(4) + 3(1)}{1(1) + 6(4) + 1(9)}$$

$$= \frac{45 + 4 + 3}{1 + 24 + 9}$$

FIGURE OF MERIT = 1.5

Order of Magnitude Technologies

In sorting out the order of magnitude technologies, the DSB panel began with a larger list of candidate technologies and technology intensive mission areas and pruned down the list using the criteria and the figure of merit (see Table II-3, List of Technology Candidates).

The list of 17 technologies which emerged from this process is shown in Table II-4. Table II-4 lists the technologies in order of priority according to the figure of merit (opportunity/risk column) and indicates the nature of impact from a system or application point of view. Table II-4 also lists the investment status of the technology which will be discussed in greater detail in the following section.

The DSB panel recognizes that the figure of merit is only one of many devices which could have been used to quantify what is essentially a judgment about the relative worth. The value of the figure of merit, however, lies in the fact that it forces the decision maker or the analysts to consider a full spectrum of issues embedded in the criteria.

Care must be taken in interpreting the figure of merit in certain cases where risk is very low (a very small denominator can overdrive the FOM). Table II-5 shows, for example, that the top 10 of 17 technologies change if one considers only opportunity (higher numbers), or risk (lower numbers) or FOM (the ratio of the two numbers).

An important aspect of planning is the window of opportunity/risk in technology utilization. Table II-6 shows the technologies which in the opinion of the DSB panel could have near term (<5 years) impact.

TABLE II-3
LIST OF TECHNOLOGY CANDIDATES

DIRECTED ENERGY: Short Wavelength Lasers; Compact Efficient Chemical Lasers; Large Space Structures; Adaptive Optics; High Gradient Electron Accel; Pulsed Power; High Power Microwaves; Neutral Particle Beams; X-Ray Lasers

RADAR TECHNOLOGY: Space Based Radar; Solid State Microwave Components

ELECTRO-OPTICS TECHNOLOGY: High Density Monolith EO/IR Sensor Systems; On-Board Data Processing (Clutter Suppression); Active EO-AO Filters; Space Coolers

COMPUTER SCIENCE: Supercomputers (including Advanced Algorithms); Advanced Software Techniques; Machine Intelligence (vision, speech understanding, inference and deduction, knowledge bases, natural languages); Education Technology; Optical Computers; Microprocessors; Based Personal Training Aids; Distributed Data Bases

COMMUNICATIONS TECHNOLOGY: Secure Survivable Communications; Distributed Communications; Integrated Data, Text and Voice Networks; Packet Switching

MICROELECTRONICS: VHSIC; Non-Volatile Solid State Memories; Gracefully Degradable Chip Architectures; Optoelectronics

POWER AND PROPULSION: Adiabatic Turbo-Compound Engines; Homopolar Electric Drive Systems; Adiabatic Turbofan Engines; Superconductive Machinery and Switch-Gear; Laser Propulsion; Electromagnetic Propulsion; Space Power

PRODUCTION AND REPAIR TECHNOLOGY: Military Robotics; CAD/CAM/CAT; Flexible Mfg Technology; Distributed Information Process Control; Quantitative Nondestructive Evaluation; Net-Shape Processing; Space Fabrication Techniques

BIOCHEMICAL TECHNOLOGY: Genetic Engineering; Microencapsulation

MATERIALS: Advanced Composite Materials; Toughened Ceramics; Rapid Solidification Technology; Compound Semiconductors; Multiphasic and Layered Compounds; Optical Ceramics

SURVIVABILITY ENHANCEMENTS: Active and Passive Stealth; ECM Technology; Satellite System Hardening (Electronics): Low Cost INS

ASW: Non-acoustic ASW; Acoustic Arrays (Clear Day, FOSS); Active Sonar, Autonomous Submersibles

SPACE WARFARE: MHV; Antiground Space Weapon

STRATEGIC OFFENSE: Terminally Guided RVs

TABLE II-4

Order of Magnitude Technologies

Technology Systems/Applications	Opportunity/Risk Nature of Impact*	Investment Status
1. VERY HIGH SPEED INTEGRATED CIRCUITS	63/13.5 = 4.7	$61.6M
• Sensor Processing • AJ Communication • Distributed Processing • Adaptive Navigation and Guidance	• Cost, Decreased Size and Power per Function* • Transparent Complexity* • Self Test and Repair • Increased Processing Power*	• Healthy • Aggressive • Emphasis on VHSIC • Needs Technology Insertion Demonstrations
2. ACTIVE AND PASSIVE STEALTH	65.5/22 = 3.0	
• Survivability in High Threat Environments • LPI Radar and Communications	• Destabilize Enemy High-Investment Threat Capabilities* • Improved "Transparency" to Radar IR and Visibility Surveillance* - Improved Survivability* - Deception*	• Adequately Funded to Exploit Available Opportunities • Meaningful Demonstrations Needed
3. ADVANCED SOFTWARE/ALGORITHM DEVELOPMENT	71/29.8 = 2.4	$7M
• Cryptography • Target Acquisition • Software Maintenance • Pervasive Across DoD Systems	• Portability of Software • Faster Software Design/Testing Maintenance* • Less Expensive Alternatives to Hardware	• Badly Underfunded Given Impact Potential • Poorly Coordinated and Conceived • Fragmented • Behind State of the Art
4. MICROPROCESSOR-BASED PERSONAL LEARNING AIDS	41/17 = 2.4	$0M
• Troop Training - procedures - maintenance - weapon laying	• Compress Training Time • Higher Skill Levels • Training Cost, Flexibility • Extends Manpower Pool	• An Opportunity Deserving Funding $4M Needed • Development of Training Software for Personal Computers • An Experiment Program of Sufficient Size to Judge Effectiveness

* Order of Magnitude Improvement

TABLE II-4 (Cont'd)

Order of Magnitude Technologies

Technology Systems/Applications	Opportunity/Risk Nature of Impact*	Investment Status
5. FAIL SOFT/FAULT TOLERANT ("SELF POLICING") ELECTRONICS	55.5/25 = 2.2	$ 6M (no central program)
• Pervasive Impact on System Availability	• Electronic System Availability and Reliability* • Life Cycle Costs* • Simplified Test	• No Coherent Program Focus • Poor Transition of Promising Technology alternatives
6. RAPID SOLIDIFICATION TECHNOLOGY	46/21 = 2.2	$20M
• High Threat/Weight Jet Engines • High Specific Stiffness Airframe and Space Structures • Armored and Marine Platforms • Advanced Magnets and S/C Machinery	• Increased Superalloy Temperature Capability • Improved Specific Stiffness • Life Extension Under Extreme Environments* • Reduction of Strategic Materials	• Adequately Funded • Tri-Service Plus DARPA Coordinated Program • Needs Industry Commitment to Processing Scale-up
7. MACHINE INTELLIGENCE	65.5/31.7 = 2.1	$13.2M
• C^2 and Crises Management • Autonomous Weapons • "Intelligent" Data Bases	• Pervasive Deployment of Computers* • Distributed Information • Recognition and Correlation* • Natural Interfacing* • Transparent Complexity* • Automatic Programming	• Predominately DARPA • Slow Service Pickup • Applications Lagging • Underfunded but Talent Limited
8. SUPERCOMPUTERS	52.5/24.5 = 2.1	$9M
• Acoustic Array Processors • BMD Radar • Advanced Hydrodynamic and Aerodynamic Modelling • Cryptography/Intelligence	• High Resolution* • Broad-Band Signal Processing • High Computational Throughput* • Automatic Programming* • Large Scale Simulations	• Inadequate Resource Allocation (Maldistributed) • Congressional Mandate (not in best interest of the country) • Need Technically Balanced Program

* Order of Magnitude Improvement

TABLE II-4 (Cont'd)

Order of Magnitude Technologies

Technology Systems/Applications	Opportunity/Risk Nature of Impact*	Investment Status
9. ADVANCED COMPOSITES	43/21.3 = 2.0	$33M
• Lightweight Fighters, V/STOL • Large Space Structures - Radar, DE Weapons • ICBMs/SLBMs	• High Specific Stiffness and • Near-zero Thermal Expansivity* • Very-High Temperature Capability (C/C Composites) • Weight Reduction	• Overall Funding Adequate • More Emphasis Needed for Metal-Matrix and C/C Composites for High-Temperature Machinery • Needs More Designer Involvement
10. HIGH-DENSITY, MONOLITHIC, FOCAL PLANE ARRAYS	58/46 = 1.3 (strategic) 45/25.5 = 1.8 (tactical)	$121M
• Indications and Warning • Targeting • Battle Damage Assessment • Launch-Under-Attack Retargeting • Theater and Ocean Surveillance • Technical Intelligence • Fire and Forget Tactical Missiles	• Early Detection • Improved Sensitivity and Resolution* • Real Time Processing* • Clutter Rejection* • MTI Processing* • Lock on After Launch • Increased P_k • Increased Survivability of Firer	• Mostly Under DARPA/STO Program • Program Consists of - System Level Proof of - Concepts for Space Applications - Technology Demonstrations - Phenomenology Research • Funding Level Adequate
11. RADIATION HARDENED, ADVANCED ELECTRONICS	43/25 = 1.7	$9M (?)
• Pervasive Impact - All Strategic and Space Systems - Tactical Sensors and C^3	• Survivability*	• Current Work is Fragmented • Need Emphasis on Advanced Sensor Hardening • Central Effort of $15
12. SPACE NUCLEAR POWER	52/34 = 1.5	$1M
• Advanced Space Based Radars and Directed Energy Weapons • Multi-purpose IR Battle Management Systems • Military Man in Space	• Power/Weight* • Cost per Delivered kw*	• Minimal Effort Ongoing at LASL • Need $10M Aimed at Demonstration

* Order of Magnitude Improvement

TABLE II-4 (Cont'd)

Order of Magnitude Technologies

Technology Systems/Applications	Opportunity/Risk Nature of Impact*	Investment Status
13. HIGH-POWER MICROWAVE GENERATORS	56/40.3 = 1.4	$0.6M
• mm-Wave Radar • LPI Communications (mm-Wave) • Anti-Sensor/Anti-Electronics Weapons • Anti-Personnel Weapons	• Limits Impact of EO/mm-Wave PGM's • High Multiple Shot Capability* • Power/Performance (gyrotrons, mm-Wave/FEL)*	• Navy Directed Energy Program (0.6M) • $5-10M Needed to Address Target Vulnerability and Hardening • Seriously Underfunded to Exploit Anti-Sensor and Anti-Personnel Weapons
14. LARGE SPACE STRUCTURES	58.2/44 = 1.3	$6M (DOD), $18M (NASA)
• SAME AS FOCAL PLANE ARRAYS AND SPACE BASED WEAPONS	• High IR Resolution and Sensitivity* • High Gain* • Large Surveillance Coverage* • Large "Instantaneous" Lethal Range*	• Total Program Inadequate to Address Efficient Erection • DoD Program Aimed Primarily at Adaptive Optics • NASA Programs Aimed Primarily at Building Lightweight Structures from Metallic Ribbons • DoD-NASA Coordination Needed to Define Down-Stream Demonstrations
15. OPTOELECTRONICS	37/28.25 = 1.3	~$15M
• Combined Voice, Data, and Video Communications • Remote Vision and Sensors • Broadband More Survivable Data Links	• Protection from EMI, EMP, and Ground Loops* • High Data Rates • Weight and Volume Reduction • Cost Reduction	• Mostly Fiber Optics • Includes Combined Device Technology and Several Demonstration Projects • Funding Adequate
16. SPACE BASED RADAR	43/33.25 = 1.3	$4M
• NRT Tactical and Strategic Surveillance and Targeting	• "Worldwide" Coverage*	• Study/Tradeoffs Underway

* Order of Magnitude Improvement

TABLE II-4 (Cont'd)

Order of Magnitude Technologies

Technology Systems/Applications	Opportunity/Risk Nature of Impact*	Investment Status
17. SHORT WAVELENGTH LASERS	63.2/54 = 1.2	$8.3M
• Laser Weapons, BMD Capability • Submarine/Aircraft Communications	• "Instantaneous" Lethal Range* • Weight in Orbit* • Fast Slew Rate* • Multiple Shot Capability	• Underinvested in this High-Leverage Area (Short Wavelength, High Power Lasers) • Funding Mostly DARPA (Large Demonstration Programs are Constraining Research)

* Order of Magnitude Improvement

TABLE II-5

TOP "10"
TECHNOLOGY ORDERING

BY OPPORTUNITY (HIGH)	BY FOM (HIGH)	BY RISK (LOW)
Advanced Software Algorithms	Very High Speed Integrated Circuits	Very High Speed Integrated Circuits
Stealth	Stealth	Microprocessor-Based Personal Learning Aids
Machine Intelligence	Advanced Software/Algorithms	Rapid Solidification Technology
Short Wavelength Lasers	Microprocessor-Based Personal Learning Aids	Advanced Composites
Very High Speed IC	Fail Safe, Fault Tolerant Technology	Stealth
Large Space Structures	Rapid Solidification Technology	Super Computers
High Density FPAs	Machine Intelligence	Fail Safe, Fault Tolerant Technology
High Power Microwaves	Super Computers	Satellite System Hardening
Fail Safe, Fault Tolerant Technology	Advanced Composites	High Density Monolithic Focal Plane Arrays (Tactical)
Super Computers	High Density Monolithic Focal Plane Arrays (Tactical)	Optoelectronics

TABLE II-6

ORDER OF MAGNITUDE TECHNOLOGIES THAT COULD HAVE NEAR-TERM (<5 YEARS) IMPACT

(FOM)	
4.7	Very High Speed Integrated Circuits
4.2	Packet Switching
4.2	Integrated Data, Text, and Voice Networks
3.0	Stealth
2.8	Distributed Data Bases
2.6	Adiabatic Turbo-Compound Engines
2.4	Advanced Software/Algorithm Development
2.4	Microprocessor-Based Personal Learning Aids
2.4	Space Coolers
2.2	Rapid Solidification Technology
2.1	Super Computers
2.0	Advanced Composites
1.8	High Power Microwave Generators

D. INVESTMENT STRATEGY FOR TOP "17"

The DSB panel examined the nature and quantity of resources being dedicated by DoD to development/application of the Top "17". In performing this evaluation, the panel asked a series of questions which could be considered in retrospect as an investment "catechism".

- What is it? What is this effort trying to accomplish (defining the technology sufficiently well to discriminate it from other similar technologies)?

- Why is it important? Assuming success, what difference can it make to the user or in a mission area context (taking into account the nature and limitation for current practice)?

- What is the current status? What is the DoD program? What should it be? What is new about the proposed effort and why will this approach be successful?

- How long will it take? How much will it cost? What are the measures of success?

Appendix C of this report answers these questions in some detail for each of the technologies identified (the information is also summarized in Table II-4). Some of these technologies are being adequately funded, but some are not. It should be noted that the vast majority of the "order of magnitude" technologies lie in the electronics area. Currently, the electronics area commands a relatively low percentage of the total budget. There is a need to reorder funding priorities within the Technology Base to correct this imbalance. Table II-7 lists those technologies which in the opinion of the panel are under-invested and suggests more appropriate funding levels and areas of emphasis.

The total annual level of the additional funding required to support these new initiatives is approximately $75M. These efforts are appropriately Exploratory Development efforts. Recommendations regarding increases in 6.1 and 6.3A efforts are treated elsewhere in this report.

The panel felt that there were not only deficiencies in funding, but, in certain areas, deficiencies in the way DoD has managed technology funding. Certain programs could benefit from the vertically integrated program structure of the VHSIC Program managed by DoD. Key elements of this program (summarized at length in Appendix G) are:

- Centralized management and coordination of the total Tri-Service program with fenced funding to ensure accountability.

- The inclusion under one industrial organization of all aspects of a technology's development and transition into military systems (e.g., processes, design, materials, etc.).

- Continuity of the industrial team(s) from early technology development through transition to system applications.

TABLE II-7

Underinvested Technologies that Could Make an Order of Magnitude Difference

TECHNOLOGY (FOM)	CURRENT FUNDING ($M)	RECOMMENDED FUNDING ($M)	STATUS AND NEEDED EMPHASIS
ADVANCED SOFTWARE/ALGORITHM DEVELOPMENT (2.4)	7	30	• DOD "SMARTS" ARE THIN • OPPORTUNITIES: • FAST ALGORITHMS AND AUTOMATED PROGRAMMING
MICROPROCESSOR-BASED PERSONAL LEARNING AIDS (2.4)	0	4	• FIELD APPLICATION EXPERIMENTS
SUPERCOMPUTERS (2.3)	9	15	• MALDISTRIBUTED • LARGE SCALE MODELLING
MACHINE INTELLIGENCE (2.1)	13.2	20	• APPLICATIONS WORK UNDERFUNDED BUT TALENT LIMITED • EXPERT SYSTEMS
RADIATION HARDENED ADVANCED ELECTRONICS (1.7)	5 (?)	15	• HARDENING OF ADVANCED ELECTRONIC PROCESSORS • CURRENT WORK IS FRAGMENTED
SPACE NUCLEAR POWER (1.7)	1	10	• 50-100 KW, COMPACT NUCLEAR REACTORS
HIGH POWER MICROWAVE GENERATORS (1.4)	0.6	5	• TARGET VULNERABILITY • CONCEPTUAL WEAPON DESIGN (ANTI-SENSOR, ANTI-PERSONNEL)
LARGE SPACE STRUCTURES (1.3)	6 (DOD) 18 (NASA)	12	• TECHNOLOGY INTEGRATION AND DEMO • NASA/DOD COORDINATION CRUCIAL
SHORT WAVELENGTH LASERS (1.2)	8.3 (18.5 FY82)	15 (27 FY82)	• NEW CONCEPTS • COMPLETE CRITICAL DEMONSTRATIONS

The panel identified certain of these "order of magnitude" technologies as suited for a management structure, visibility, and high level attention similar to that of the VHSIC program:

- Machine intelligence
- Advanced software/algorithm technology
- High power microwave generation
- Advanced materials (rapid solidification, advanced composites)
- Microprocessor-based personal learning aids.

Scenario-Based Technology Planning

Tables II-8 and II-9 in a sense close the loop on the planning process suggested in this chapter by correlating, in matrix fashion, the top "17" technologies with the post-1990 scenarios and the integrating factors. Table II-8 illustrates the correlation with the integrating factors and Table II-9, the correlation with the scenario-driven technical requirements summarized in Table II-1.

The process, of course is not as "cut and dry" as it appears here in its summary form. The scenario selection, for example, is an iterative process. One cannot select a scenario without having some idea of the systems and operational concepts which are going to be employed. In other words, technology drives the scenarios to a certain extent since new technology may provide a new approach to warfare and change the original scenario.

One must also keep in the forefront that the discipline entailed in the Figure of Merit methodology is more important than the numbers. This discipline is what gives the "Order of Magnitude" technologies list its credibility. The FOM suffers from the inherent problems associated with any scheme to put numbers on dissimilar factors and then attempt to measure relative importance by adding up the numbers. Inherent in such a technique is the implicit assumption that the dissimilar factors considered are all of equal relative importance, since the numerical scale is being applied to each one. Obviously, this is not necessarily so, and the FOM approach makes no allowance for such variation in relative importance of either the "opportunity" factors or the "risk" factors.

Care must be taken that one or a few of the factors given a rating do not in a sense control the "opportunity" or "risk". In Tables II-8 and II-9 for example, the matrices illustrate the pervasive nature of certain technologies like VHSIC; fail-safe; fault-tolerant electronics; machine intelligence; and electro-optics. Short wavelength lasers, on the other hand, have a critical, but rather narrow application in space.

This application alone, however, would be important enough to place it higher on the list than it achieved through the FOM calculation. A mission rating of "9" may be too small in this instance and thus become a "controlling" factor in a negative sense because the technology has narrow application and would get low scores in other categories. Likewise, among the "risk" factors there could very possibly be some "controlling" factors. In the example, the risk is moderate to low except for the "Political Bureaucratic Environment".

TABLE II-8

"Order of Magnitude" Technologies / Integrating Factors	Sustained Operations	Continuous Threat Location/Track	Real Time Information Mgmt	Counter Threat Target Acquisition	Integrate "Eyeball and Trigger"	Secure, Jam-Resist, Mobile Communications	Dispersed, Small Units	Transparent Complexity	Equipment Availability/Reliability	Operation in Extreme Environments
1. VHSIC	X	X	X	X	X	X	X	X	X	
2. Active and Passive Stealth				X						
3. Advanced Software			X	X	X	X		X	X	
4. Microprocessor Based Personal Learning Aids	X	X	X		X		X	X	X	X
5. Failsafe Fault Tolerant Electronics	X	X	X	X	X	X	X	X	X	
6. Rapid Solidification Technology							X		X	
7. Machine Intelligence	X	X	X	X	X		X	X	X	X
8. Supercomputers		X	X	X			X			
9. Advanced Composites							X		X	
10. High Density Monolithic Focal Plane Arrays	X	X		X						
11. Hardening of Satellite Electronics				X						
12. Space Nuclear Power		X								
13. High Power Microwave Generators				X						X
14. Large Structures in Space	X	X		X						
15. Optoelectronics	X	X	X	X	X	X	X	X	X	X
16. Space Based Radar				X						X
17. Short Wavelength Lasers										

TABLE II-9

"Order of Magnitude" Technologies / Scenario Driven Requirements	Continuous Operations	No Troop Concentration	Mobility, Agility, Firepower	Small Units	Seeing Deep	Integrated Operations (NUC, CH, EW)	Battlefield Expansion	Stand-off Weapons	Dispersed Base Operations	Premium on Stealth	AF Integration (ACO/Strike)	Increased Use of Space	High ECM Environment	Cruise Missile vs Air for Strike	Worldwide Surface Targeting	ASW-Long Range Localization	The Use of Space - Naval	Space Warfare	Strategic Defense	Man in Space	Sustained Strategic Operations
1. VHSIC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2. Active and Passive Stealth					X	X		X		X			X	X				X		X	X
3. Advanced Software		X		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X
4. Microprocessor-Based Personnel Learning Aids	X	X	X	X		X	X		X		X	X	X				X	X		X	
5. Failsafe Fault Tolerant Electronics	X	X	X	X	X		X	X	X		X	X	X	X	X		X	X	X	X	X
6. Rapid Solidification Technology			X					X	X					X				X		X	
7. Machine Intelligence	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X
8. Supercomputers	X	X		X	X		X				X	X	X			X	X	X	X		
9. Advanced Composites			X					X	X					X				X		X	
10. High Density Monolithic Focal Plane	X				X			X			X	X		X			X	X	X	X	X
11. Hardening of Satellite Electronics					X	X						X	X	X	X		X	X	X	X	X
12. Space Nuclear Power											X						X	X	X	X	
13. High-Power, Microwave Generators			X		X	X		X					X	X							
14. Large Structures in Space												X					X	X	X	X	X
15. Optoelectronics	X	X	X	X	X	X	X	X	X		X	X	X				X	X		X	X
16. Space Based Radar					X							X		X	X		X	X			
17. Short Wavelength Lasers																		X	X		

This factor gets a "9", apparently because it requires a change to international or arms control agreements. It is entirely possible that such a change would be so sensitive and create so much international controversy as to be totally impractical to attempt. In such a situation, it does not matter how low the risk is on the other factors; if this factor alone makes the concept totally impracticable, then the total risk factor should reflect such influence.

So long as it is recognized that all of these factors in the FOM are not necessarily of equal relative importance, and that one or some of them may be controlling, then the approach can be extremely useful. In further development of the FOM for planning purposes, some method should be divised for taking into account the relative importance of various factors under particular circumstances. Such a method must recognize the potential for "controlling" factors.

CHAPTER III

EVALUATION OF CURRENT TECHNOLOGY BASE INVESTMENT

CHAPTER III

EVALUATION OF CURRENT TECHNOLOGY BASE INVESTMENT

A. TECHNOLOGY BASE INVESTMENT

In the course of its evaluation of the Top 17 critical technologies, the DSB Panel attempted to:

- Ascertain the overall technology base investment strategies of OSD and the Services.
- Develop a structure for collectively displaying these diverse strategies in terms of FY 1981 resource allocations.
- Provide a broad perspective on the nature of current technology base investment strategy.

Representatives from OSD and the Services provided the Panel with briefings on their respective strategies, the major elements of which are summarized below.

1. DoD Technology Base Investment Strategy

OSD provides an assessment of the overall DoD technology base investment strategy. The highlights of such strategy are documented in the Technology Area Descriptions (TAD). These TADs include:

- Basic program description
  - Broad objectives
  - Fiscal summary
  - Representative program thrusts
- Program analysis
  - Correlation of program with technology needs of mission area summary
  - Major technological oportunities
  - Accomplishments (technical and management)
  - Technology exchange and intelligence assessment
  - Program strengths and weaknesses
- Management strategy
  - Technical goals
  - Long range trends

The technologies highlighted at the OSD level as being more important are:

- Very high speed integrated circuits (VHSIC)
- Manufacturing technology
- Precision guided munitions in a battlefield environment
- Advanced materials
- Directed energy
- Chemical warfare

2. U.S. Navy Technology Base Investment Strategy

The Navy 6.1 and 6.2, which is under one commander, the CNR/CND, formulates its technology base thrusts on the basis of near and long term naval needs emanating from the Chief of Naval Operations' deficiency and need statements. Mission and Technical Area Strategies are then developed in response to these needs for the exploratory development phases. The planned overall technology base investment strategy is:

6.1	6.2
25% Basic research closely associated with potential application	33% Generic technologies (new, emerging, state of the art advancement)
75% Evolutionary research across the spectrum of disciplines (1/5 high risk/high payoff)	67% Focused technology work which addresses specific operational needs

The following technology areas have been identified by the CNO, in concert with the CRN/CND, as holding unusual promise for the Navy for the next 10 or 15 years:

Electronic Devices
Materials
Artificial Intelligence and Robots
Computing
Millimeter/Microwave Sensor/Sources
Fiber Optics (including sensors)
Surveillance and Guidance
Space Technology
Signature Reduction
Directed Energy
Insensitive Explosives

In an effort to emphasize programs in these and other areas, the Navy has established a series of 6.1 and 6.2 Special Focus Programs. For example, some of the most significant new initiatives in FY82 include:

Advanced Common Intercept Missile

Broadband Passive Sonar Processing
CW/BW Defense
High Performance Undersea Weapon Warhead
Large Aperture Submarine External Array
Marginal Ice Zone
Masking Surface Ship Noise
Solid Dielectrics
Spaceguard
Strategic Sea Straits
VLSI Architecture

3. Air Force Technology Base Investment Strategy

The Air Force investment strategy results from several diverse but related activities, namely:

- Development of a long range technology strategy by the Director of Plans, Air Force Staff.

- The Air Force Systems Command (AFSC) analysis and planning effort under Project Vanguard which:

  - analyzes the future threat to mission effectiveness and the nature of projected system deficiencies.

  - provides recommendations on system development priorities.

- Analysis and investment strategy efforts of the Director of Air Force laboratories which rely heavily on technical inputs from the Air Force laboratories.

4. U.S. Army Technology Base Investment Strategy

The Army's investment strategy evolves through the interactions occurring in its established Research, Development and Acquisition Process. A key element inserted into this process is the Airland Battle 2000 concept which projects twenty years into the future and was developed to guide, inter alia, future material acquisitions, and to ensure a concept-based requirements system. This concept provides a basis for additional, more detailed mission area analyses which, in turn, identifies specific deficiencies vis-a-vis the threat, defines and prioritizes material operational needs and develop funding goals which are then addressed by the development community in science and technology plans developed for each mission area.

Based upon analysis to date, the following technologies are the highest priority for Army investment:

- Armor/anti-armor technology (reactive armor, active armor, advanced materials, test bed prototypes, improved conventional armament systems, HAW/MAW, hypervelocity rocket, top attack weapons, tank gun ammo improvements)

- Microelectronics (very high speed integrated circuits, special purpose LSI/VLSI, ultra high frequency circuits)

- Electro-optics technology (far infrared focal planes, automated sensors, low energy lasers, optical/EO CCM, EO models, special purpose sensors)

- MM wave technology (MM wave components, radar, PGM, missile guidance, EW demonstrations, communications)

- Chemical warfare technology (individual protection, CB detection and warning, decontamination, collective protection, training, chemical deterrence, smoke-obscuration)

B. "GAMEBOARD" APPROACH TO REVIEWING INVESTMENT STRATEGY

As is evident, the DoD technology base investment is very complex. In its attempt to understand the total DoD investment the DSB Panel identified two different kinds of risk associated with technology development: (1) Technology Risk - a measure of the difficulty of achieving performance thresholds necessary for success in a military application, and (2) System/Mission Risk - a measure of the institutional difficulties of transitioning a technology into an operational system due to the impact on doctrine and operations. To gain a perspective on how the DoD is actually allocating its technology base resources in terms of these risks, the panel created a table which treats these types of risk as separate variables, the "Gameboard" (Table III-1). This type of assessment was not intended as a method for developing the technology base plan, but, rather, as a retrospective review of the plan.

The OSD and DARPA program managers were given this table and asked to distribute their FY 1981 program among the quadrants. Table III-2 summarizes the results of this effort.

These results are quite interesting. They show that DoD invests heavily in two quadrants: (1) the high technology risk, high mission risk quadrant (e.g., programs such as DARPA's Directed Energy Program); and (2) the evolutionary quadrant (programs such as aerodynamics and navigation). The most important result of looking at the DoD technology base investment using this approach is the identification of the very low emphasis placed on the upper left-hand quadrant, the low technology risk, high mission risk area.

C. ANALYSIS OF ASYMMETRIES IN GAMEBOARD

When one views the dollars allocated by the DoD to the major technology areas (Table III-3), some question could arise as to the balance or consistency of the funding levels based on future need. The Panel sought to examine the distribution of dollars on the "gameboard" (see Table III-4) as a means of gaining insight into the way the DoD funds technology. The following comments are meant to highlight what appears to be some of the consistencies and inconsistencies in funding patterns in terms of general technology areas:

TABLE III-1

TECHNOLOGY BASE "GAMEBOARD"

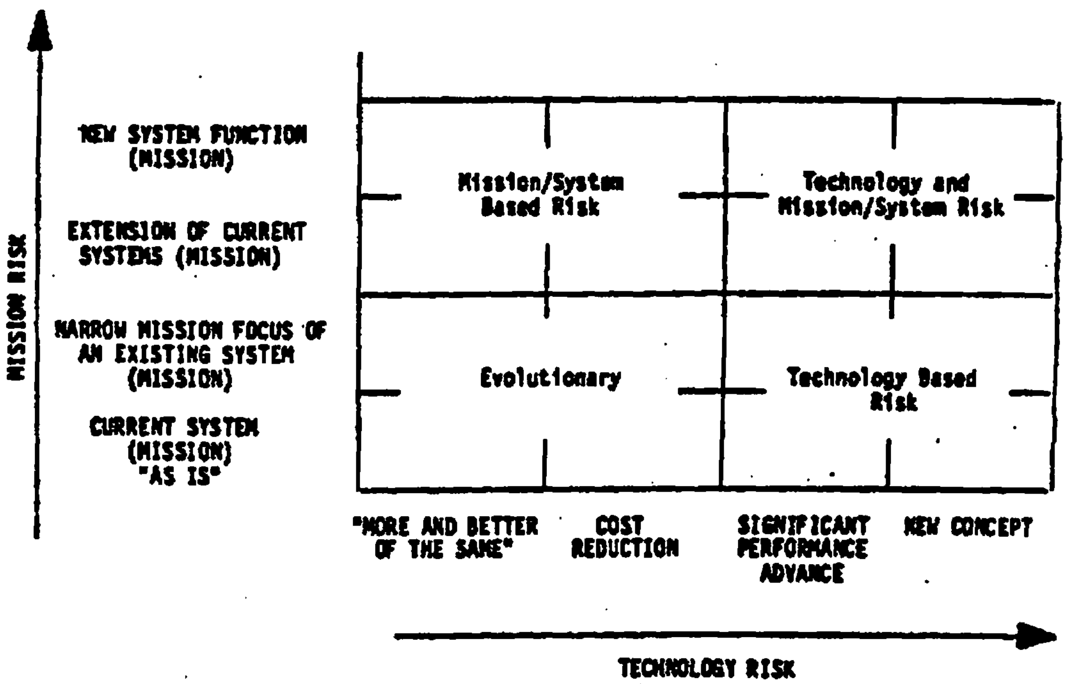


TABLE III-2

FY81 TECHNOLOGY BASE PROGRAM

SYSTEM/MISSION RISK

	"MORE AND BETTER OF THE SAME"	COST REDUCTION	SIGNIFICANT PERFORMANCE ADVANCE	NEW CONCEPT
NEW SYSTEM FUNCTION (MISSION)	$6.0M	$35.0M	$116.6M	$342.45M
EXTENSION OF CURRENT SYSTEMS (MISSION)	$89.4M	$66.0M	$307.1M	$232.85M
NARROW MISSION FOCUS OF AN EXISTING SYSTEM (MISSION)	$119.2M	$47.1M	$108.2M	$143.7M
CURRENT SYSTEM (MISSION) "AS IS"	$425.6M	$377.3M	$227.2M	$122.1M

TECHNOLOGY RISK

TABLE III-3

DOLLAR ALLOCATION BY MAJOR TECHNOLOGY AREA

1.	Computer, Networks, and Software	$110.3M
2.	Materials	111.1
3.	Directed Energy	127.2
4.	Microelectronics and Electronic Devices	133.4
5.	Communications	75.2
6.	Navigation, Guidance and Control	75.0
7.	Microwave Devices	30.0
8.	Vehicular Technology	359.0
9.	Optics	5.3
10.	Sensors	299.3
11.	Power and Propulsion	248.0
12.	Munitions	233.5
13.	Anti-Submarine Warfare*	180.2
14.	Education Technology	48.6
15.	Manufacturing Technology	174.7
16.	Chemical Warfare/Biological Warfare	6.4
17.	Electronic Warfare	35.5
18.	Biochemical Technology and Genetic Engineering	94.4
19.	Other	234.0

* The programs directly tied to ASW (e.g., undersea acoustics and non-acoustic) are shown here, certain other technologies have an impact on ASW (e.g., sensors).

TABLE III-4

DISTRIBUTION OF DOD FY81 TECHNOLOGY BASE BY MAJOR TECHNOLOGY AREA

	"MORE AND BETTER OF THE SAME" / COST REDUCTION	SIGNIFICANT PERFORMANCE ADVANCE / NEW CONCEPT
NEW SYSTEM FUNCTION (MISSION) EXTENSION OF CURRENT MISSION/SYSTEM	1. Computers, Networks, and Software ($21.3M) 4. Microelectronics and Electronic Devices ($29.0M) 8. Vehicular Technology ($68.7M) 10. Sensors ($10.0M) 11. Power and Propulsion ($24.0M) 13. ASW ($28.0M) 14. Education Technology ($6.0M) 19. Other ($34.0M)	1. Computers, Networks, and Software ($50.2M) 2. Materials ($30.2M) 3. Directed Energy ($272.0M) 4. Microelectronics and Electronics Devices ($68.2M) 6. Navigation, Guidance and Control ($35.0M) 7. Microwave Devices ($30.0M) 8. Vehicular Technology ($98.1M) 9. Optics ($1.7M) 10. Sensors ($125.1M) 11. Power and Propulsion ($81.0M) 12. Munitions ($47.2M) 13. ASW ($21.0M) 15. Manufacturing Technology ($4.2M) 17. Electronic Warfare ($35.0M) 18. Biochemical Technology and Genetic Engineering ($28.0M) 19. Other ($148.3M)
NARROW MISSION FOCUS OF AN EXISTING SYSTEM (MISSION) CURRENT SYSTEM (MISSION) "AS IS"	1. Computers, Networks, and Software ($25.4M) 2. Materials ($23.0M) 5. Communications Technology ($28.0M) 6. Navigation, Guidance and Control ($40.0M) 8. Vehicular Technology ($127.6M) 10. Sensors ($60.0M) 11. Power and Propulsion ($114.0M) 12. Munitions ($55.4M) 13. ASW ($83.4M) 14. Education Technology ($40.0M) 15. Manufacturing Technology ($174.7M) 16. CW/BW ($6.0M) 18. Biochemical Technology and Genetic Engineering ($68.6M)	1. Computers, Networks, and Software ($33.2M) 2. Materials ($8.0M) 4. Microelectronics and Electronics Devices ($36.3M) 5. Communications Technology ($10.1M) 8. Vehicular Technology ($64.2M) 9. Optics ($3.4M) 10. Sensors ($100.2M) 11. Power and Propulsion ($29.0M) 12. Munitions ($132.9M) 13. ASW ($47.0M) 14. Education Technology ($2.0M) 17. Electronic Warfare ($0.5M) 19. Other ($56.7M)

"MORE AND BETTER OF THE SAME" — COST REDUCTION — SIGNIFICANT PERFORMANCE ADVANCE — NEW CONCEPT

TECHNOLOGY RISK

1. Computer and Networks

- Distributed fairly evenly among quadrants.

- Commercial industry has dominant technology/R&D drive, and leads in application. This lead argues for a significant emphasis on the Mission/System-based risk area. Such emphasis does not exist.

2. Materials

- The distribution within the "gameboard" seems appropriate.

3. Directed Energy

- This technology area is, by far, the largest single area in any one quadrant. The issue here is payoff/risks versus large dollar levels required.

4. Microelectronics and Electronic Devices

- The relative distribution among the quadrants seems out of line. Since commercial R&D is an important R&D driver, there should be more emphasis in the mission/system-based risk areas.

5. Communications Technology

- The balance seems appropriate.

6. Navigation, Guidance and Control

- Navigation, guidance, and control efforts are distributed in two quadrants (Evolutionary Technology and System-based risk);

- The high risk effort seems too high given the maturity of many key technologies and of the probable payoff.

7. Microwave Devices

- No low risk entries are shown on the gameboard. It seems that there should be some support in the system/mission-based risk area for new concepts in EW, etc.

8/11. Vehicular Technology/Power and Propulsion

- The overall dollar levels seem high in light of the probable payoff, especially in comparison with sensor, computer, and software technologies.

- The difficulty in bringing this number down is that platform R&D is very high cost.

9. Optics

- Optics is in right quadrant (high risks) but totals only $5.3M. This may be adequate since the real "order of magnitude" optics (adaptive optics), is covered under other titles.

10. Sensors

- This technology area seem to have too little (in comparison with other quadrants) in the Mission/System-based risks quadrant.

12. Munitions

- There should be some investigation of the low technical risk, high mission/system risk quadrant in this technology area. There is no effort identified.

13. ASW

- ASW is well distributed in quadrants but the resource level seems low. The limitation is probably one of too few technical opportunities.

14. Education Technology

- Education technology should be less evolutionary (since this is commercially driven) and more oriented toward overcoming mission/system-based risk.

15. Manufacturing Technology

- It is interesting there is no funding in Mission/System-based risk quadrant for manufacturing technology. DoD should be looking at new but low risk manufacturing technology for quantum jumps in mission capability.

16. CW/BW

- This area is underfunded if one considers the extent of the Soviet threat.

18. Biochemical and Biomedical Technology and Genetic Engineering

- Most of the emphasis is on biomedical and little on genetic engineering. Industry push is on the use of genetic engineering for drug/biochemical production and is sufficient to move the technology. DoD needs to emphasize military applications including preventive medicine.

The above discussion is not intended to be a conclusive evaluation with regard to the current investment strategy. The DSB panel did, however, find the "gameboard" analysis to be a useful exercise and recommends that ASD(R&T) and the Service technology base managers consider using it in their own planning strategies as a means of balancing risk and opportunity in their pursuit of a coherent investment policy.

D. ADEQUACY OF THE TOTAL LEVEL OF TECHNOLOGY BASE FUNDING

The DSB summer study panel found no rationale for judging the total magnitude of the DoD technology base investment as too little or too much. The focus of criticism concerning the DoD's program is the organization and management of this program. The DSB panel felt that major gains could be had in the actual output of the technology base program through:

- Greater usage of "vertically integrated" programs (See Appendix H)
- Elimination of redundancy of efforts among the Services and in areas of common interest with NASA (e.g., remote sensing, propulsion)
- Reduction of the in-house execution of the basic research program (6.1)

CHAPTER IV

TECHNOLOGY TRANSITION

CHAPTER IV

TECHNOLOGY TRANSITION

The question of technology base can be viewed at different levels and from various points of view:

- Maintenance of an adequate technology base for supporting a broad spectrum of military needs.

- Identification of new and innovative technology for military systems.

- Successful transition of new technology into the military systems.

This later aspect is of primary importance and yet is often one of the biggest barriers in providing U.S. forces with capable systems at affordable cost. In the context of the military balance in terms of lead and lag, the length of the technology transition period is crucial.

The DSB panel identified a number of barriers to the successful transition of technology:

- Partitioning the research, development, and production process into separate organizations and contractors

- Lack of involvement of potential users in the establishment of requirements and the resulting programs

- Lack of fenced budgets to allow the product activities to fund transition of desired technology

- The failure to meet an "opportunity window"

- The lack of a risk/reward system

- Existence of a mature hardware option.

Adopting a new idea or concept is at the heart of the matter but it has been difficult for both government and industry alike to "institutionalize" the process of innovation. Some would assert that industry is more successful at innovation because it is driven by different forces. What follows is a discussion of the problems of adopting innovations; the nature of innovation; the nature of the transition process and how government and industry differ in their approaches to innovation; and suggestions as to how DoD might better handle the process of technology transition through the use of a new approach - "Test Marketing."

A. THE PROBLEM OF ADOPTING INNOVATION

For the purposes of this discussion, the process of innovation was characterized as follows: invention, the generation of the idea; development, the reduction to practice; adaption, the implementation of the idea; diffusion, the wide acceptance of deployment in systems. All four are required if technology innovation is to succeed. It is interesting to note differences and some similarities in the way industry or commercial enterprise and government handle the question of technology innovation.

1. Nature of the Government Process

Idea generation in the area of technology for national defense is found both in industry and in various in-house government efforts (DARPA, Service Laboratories) with 6.1, 6.2, and independent research and development (IR&D) type funding support. Programs are usually small with low visibility and not much bureaucratic interference.

As an idea is developed or reduced to practice, there is a larger infusion of resources and resistance as innovation begins to build. Whether development takes place in a government laboratory or an industry (6.3, IR&D funding), the innovation by nature threatens other competing and/or existing systems and thus may require a strong "user" endorsement.

Adoption in the government case usually requires a good relationship between the technologist and the user, and, in most cases, a person to champion the cause of innovation since the acquisition management structure will generally oppose innovation.

2. Nature of the Industry Process

In the case of industry, idea generation can come at any level (R&D, engineering, marketing). Since IR&D or government contracts are limited, there is more control exercised and perhaps a stronger incentive to come up with "winners."

Reduction to practice engages the engineering and advanced systems sectors of industry with higher levels of resources but also with tougher scrutiny since the idea must now stand up to return-on-investment (ROI) and market factors. A champion within industry is usually required at this point to move ahead with the innovation.

Adoption involves customer acceptance and participation in funding of the idea. Here competition is crucial since industry must consider company profitability, payback period and share of the market generated by the innovation. The new technology at this stage may continue to require a champion and even political alliances to move it along.

3. Differences

Industry is driven not only by its own R&D organizations but also by its perception of user need, the market value of the innovation, the market share it generates, and other considerations like ROI and payback period. Government, on the other hand, is motivated differently. It must accept ideas from its own in-house efforts or from industry, but the internal politics which dominate decision making are shielded, in a way, from market forces. There is a strong incentive to pursue low risk options.

4. Similarities

Both industry and government share certain tendencies which inhibit innovation. As large organizations, they share a natural resistance to change and usually allocate a disproportionate amount of resources to maintaining the status quo. There is a structured approach to the allocation of R&D funds which may not be responsive to change in the environment. The time constant for change in any large organization is long.

B. NATURE OF INNOVATION

Table IV-1 lists seven observations which could be made about the nature of technology innovation and factors which contribute to or retard the adoption. Innovation, as distinct from invention, refers to the actual application of a new device, system, or method of operation. Understanding innovation in the defense context is complicated by the fact that DoD does not keep good archival records, that participants in the process have strong biases, and finally, that it is difficult to assess, through unobtrusive measurement, the status and worth of innovations.

1. Innovation is a Political Process

It is not possible to understand the mechanism by which decisions are arrived at without resorting to a political perspective. While economic, financial and technical considerations impose constraints, the decisions themselves are the result of intergroup bargaining -- in short, a political process. In the case of concepts or equipments which have yet to be adopted, both technical and economic analyses accompanying the presentation to the decision authority are largely based on assumptions. Thus, the decision maker is seldom faced with black and white decisions.

As a result, and because invariably any technological change has its impact on the power structure of an organization, decisions on adoptions of innovations are driven not by the seemingly accurate technical or economic analyses, but by the invisible underlying political forces. In essence, the activity from which decisions emerge is characterized by compromise, accommodation and bargaining among groups with diverse interests, so that the result is not necessarily chosen as a solution to a problem but a result of compromise and possibly even confusion.

TABLE IV-1

INNOVATION ADOPTION - THE HYPOTHESIS

A. NATURE OF THE PROCESS	B. ORGANIZATION STRUCTURE	C. POLICIES AND REGULATIONS
A-1 The process of innovation adoption is a political process.	B-1 The greater the diversity of an organization the smaller the proportion of proposed innovations which will be adopted.	C-1 The quantity of R&D funding is not necessarily the decisive factor in innovation adoption.
A-2 The existence of other viable and technologically mature hardware options is one of the most powerful innovation retarders.	B-2 Separate chains of command for the R&D and design organizations spatially separated and lacking effective integration mechanisms, hinders innovation adoption.	C-2 Personnel policies which create anti-risk taking incentives for the Washington military executive, tend to retard innovation adoption.
A-3 The lack of an innovation champion strongly retards innovation adoption.		

2. Mature Hardware Options Retard Innovation

Incremental improvement is one of the biggest enemies of innovation. Even when an innovation is technically mature enough for adoption and offers potential for superior performance when compared with already accepted options, its acceptance can be retarded by the mere fact that already accepted options could provide sufficient performance without the risk of "unknowns."

Most innovations are faced with a number of hardware system competitors, many well entrenched since they have provided the function up to that time. Operators are familiar with the characteristics of equipments and are set up to maintain and repair them with vast organizations. In addition, manufacturers have a large capital investment in facilities and tools for producing the current generation of weapons. In short, the old method of operation has a well-established infrastructure.

Furthermore, if the new product does not completely replace the old but merely provides another option to perform the same general functions, then it will have a more difficult time being accepted.

3. The Champion is Essential

A strong advocate is required in order to promote innovation since the political process and the existence of alternates are potent obstacles to change. The system as it presently exists has strong built-in incentives against the emergence of champions, although such champions have emerged historically within programs where innovation was adopted (e.g., Admiral Rickover and nuclear propulsion).

V. Davis in "the Politics of Innovation"* identified four distinct characteristics of an innovation champion in each of three naval case studies he investigated.

a. He is a man from the broad middle ranks.
b. He is not the inventor of the innovation he promotes.
c. He is a passionate zealot.
d. He does not pay attention to possible consequence for his career.

4. Diversity and Organizational Structure Impact Innovation

The greater the diversity of an organization, the smaller the proportion of proposed innovations which will be adopted. Researchers studying the innovation process have recognized that innovation is not an instantaneous act; it is a process which occurs over a period of time and consists of a series of actions. The more complex the organizational framework, the more complex will be the decision making process. The consequences of innovation adoption affect many members of the organization.

---

* Davis, V., "The Politics of Innovation," Graduate School of International Studies, University of Denver, Vol. 4, Monograph 3, 1966-1967.

With an organization the size and complexity of the DoD and the Military Departments, it is no surprise that innovation adoption is a continuing problem. Different organizations within the organization are competing for funds, sometimes with differing or opposing interests. Innovation can effectively be stopped by being postponed.

5. Clear Lines of Communication are the Key to Success

Separate chains of command for the R&D and design organizations spacially separated and lacking effective integration mechanisms hinder adoption. To develop new products within a large corporate structure, the R&D organization must gather, process and transmit information to perform the basic problem solving and coordinating requirements of its component areas. Communication flow is the primary mechanism for effecting this information transfer.

AT&T and other large corporations have found that a flow of information and feedback is essential in transitioning innovation technology from Basic Research, to Applied Research, to Development and Design, to Engineering, and ultimately to manufacturing. The process can be inhibited if spatial and/or organizational barriers impede the flow of information. In the case of AT&T, it was necessary to create a spatial bond between organizationally separate entities by moving Bell Laboratories Development and Design Group into the premises of the Western Electric where it could interact with the Engineering Group. (Ref: Leopold, R., Innovation Adoption in Naval Ship Design; Naval Ship Engineering Center; May 1977.)

Many laboratories within DoD and the services are not only spatially and organizationally separate but are even competitive and antagonistic in cooperative ventures and work at cross purposes. This hinders the transition of innovative technology into systems. The laboratory competition with industry is also a significant hindrance to the transition of new ideas.

6. The Quantity of R&D Funding is not Decisive

There is a common fallacy that the level of innovation is a strong function of the R&D resources expended. This fallacy is so pervasive that certain industries' innovative image is judged on the percentage of sales contributed to R&D, assuming that the higher the percentage, the more innovative the firm. The same factor is frequently used in comparing innovativeness of world military powers who spend significant sums on R&D.

Innovation in many military systems is often not the product of in-house lab developments but rather adoption of commercial or foreign defense R&D. Innovation is found not only in big firms but in some small but creative high technology firms (computers, microprocessors, genetic engineering.) It is clear that technology innovation is only partly related to the level of investment in research.

7. Personnel Policies

In government, unlike private industry where the existence of a viable business may depend on successful innovation, there seems to be no negative consequences for those who fail to adopt sensible innovations. There are, however, definite consequences for the innovation advocate who loses. Champions do emerge, but they do so at some peril to their career. The system tends to reward those who keep their organizations out of trouble.

The frequent rotation of military offices may in itself be an inhibitor to innovation because it does not allow for the maturing of an innovation champion within the system. When an innovation is proposed, resistance usually builds within various segments of the organization followed by a fight in which a winner emerges. Even though the battle is lost, the war for innovation is not lost. But, as a new military executive arrives, the opposition forces reopen the case and the battle is regained. A winner again emerges, the cycle is repeated; innovation is postponed.

C. THE TRANSITION PROCESS

The DoD could create conditions conducive to innovative adoption in government by:

- Transferring some of the system design function to industry
- Creating stronger integrating mechanisms between R&D and design communities
- Introducing organizational and environmental changes to encourage the emergence of innovation advocates
- Diminishing the hold of the acquisition manager by strengthening the in-house design/technology manager.

The link between the developer and the user is very important. If the customer is a participant in the selection of technologies to be used for systems, the chances are high that he will accept that technology as a solution to their needs. This does not mean that all technology base work should be limited to those items or areas where strong customer support is evident, but it does point to the need for a strong alliance between user and technologists.

1. Definition of Requirements

A clear definition of the user requirements is essential if the development community is to meet actual operational needs. It should be clear that the user community is not as technologically sophisticated as the R&D community and the burden is therefore on the R&D community to explain and even "sell" the technology possibilities. The requirements determination stage should have the following attributes:

- The threat is well-defined and realistic (including adequate treatment of feasible threat response to U.S. developments).

- Technology assessments are objective (what state-of-the-art is available with what risk and at what cost; adequacy of industrial base to support wartime surge).

- System definition/design is a good balance of:

  - Cost
  - Technical Risk
  - Ability to Counter Perceived Threat (perhaps exploiting asymmetries in U.S. and adversary operational and technical capabilities):

    -- qualitatively - adequate operational capability, and quantitatively - sufficient numbers deployed

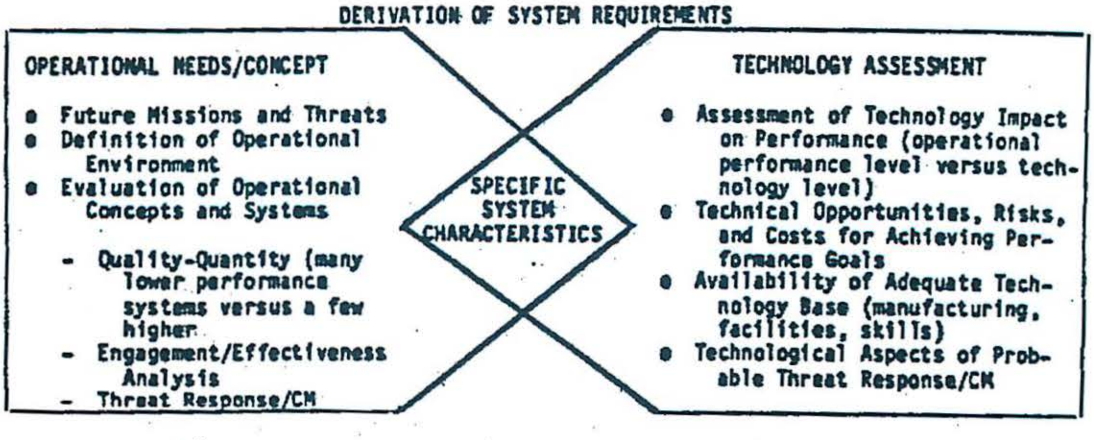
    -- growth potential - (Preplanned Product Improvement and/or Multimission Capability)

An extremely difficult but necessary element of the requirement determination process is the ability of program managers and staff to interface and integrate new or evolving operational concepts ("Top-Down Approach") with technical opportunities or risks which may support or limit a particular system design ("Bottom-Up Approach").

2. Linking Operational Concepts to Technology Innovation

The figure below depicts the interactive nature of the process which relates a range of operational needs and concepts to the range of technological possibilities. The shaded area illustrates the narrowing of focus to a specific system design.

DERIVATION OF SYSTEM REQUIREMENTS



3. Advanced Development and Production

The problem of transitioning technology to production may lie less in the early development of the technology itself and more in the area of design and engineering, the later phases of the process, specifically:

- inadequate effort in early design and test phase
- insufficient incentives for quality
- fragile bases of supply.

Budget profile, manufacturing technology, and quality assurance have a large impact on the success of transition. Production is often initiated without a sufficient understanding of either the technology or the application. If advanced development is underfunded as it often is, the real cost can escalate dramatically in later stages to overcome a bad design.

In high technology areas, DoD has had both successes and failures in transitioning technology. Table IV-2 lists four groups of technologies drawn from the space program, illustrating both the good and the bad:

a) Success - These are the numerous new products and materials which successfully transition into military space systems.

b) Not Yet Ready - These technologies still show promise but have not made it out of the laboratory yet for full scale production.

c) Looked Good on Paper - They failed because the space environment induced unexpected reactions.

d) Have Not Really Made It Yet - "Old" technologies whose failure mechanisms were either never understood or where quality assurance was, and is, inadequate.

4. Need for Quality

Over seven years ago a study called Electronics-X showed that there was a linear relationship between product cost and failure rate. The constant that related the two variables depended on product type (e.g., avionics in military aircraft) and management method (e.g., DoD standard procurement practices.) In today's terms, the study showed there would be an average of one failure per hour per $10M unit cost. A $5M aircraft radar, in other words, would fail about every two hours.

Certain systems like spacecraft do not follow this law. Project managers cannot afford failures in space, so many more resources are concentrated in the engineering design, advanced development, and testing stages, just where they should be. The quality is built in from the beginning and the result is a system which works with high reliability.

Ironically, the present trend toward cheaper systems with older technology may end up costing more in the long run. In order to save, the RDT&E budget

TABLE IV-2

DOD TECHNOLOGY TRANSITIONS -- SUCCESSES AND FAILURES FOR SPACE SYSTEMS*

SUCCESS

- Graphite-epoxy composite antennas
- Rocket nozzles using carbon-carbon and silica phenolic materials
- Elastomers for containment of hydrazine
- Ablative heat shields
- Laser beacons and low-power lasers
- Solid-state detectors for nuclear particle detection
- HgCdTe long wavelength sensors
- Kapton insulator
- Frequency synthesizers
- Voltage control and crystal oscillators
- Electronic control systems
- High-temperature ceramic multi-layer boards
- Solid-state electronics and micro-electronics
- Inertial guidance

NOT YET READY

- Metal matrix composites
- Pyrolytic graphite rocket chambers
- Atomic clock
- High performance PbS Detectors
- Gallium-Arsenide field effect transistors
- Lasers (high power)
- Vuilleumier (VM) refrigerators
- HgCdTe IR detectors
- Spectral filters
- Electron-beam welding of integrated circuit boards
- "Beam" lead technology for micro-electronics

LOOKS GOOD ON PAPER BUT FAILED IN SPACE ENVIRONMENT

- Graphite-epoxy -- outgassing in space
- Teflon coatong -- cold flow
- Spacecraft coatings -- Discolored
- Astroquartz -- unexpected charging in orbit
- Aluminized Mylar film -- became brittle in space
- SSI, MSI, LSI, AND VLSI -- Cosmic ray effects (soft errors and latch up)
- Star Sensors -- became noisy after exposure to radiation
- Stainless Steel -- fail at cryogenic temperatures
- CMOS -- techniques to increase yield also decreased hardness

HAVE NOT REALLY MADE IT YET

- Travelling-wave tubes
- Batteries
- Rubidium atomic clocks
- PbS polycrystalline IR detectors
- High-voltage electrical wire
- Parachute recovery hardware
- B-nuts in space-system plumbing
- Ball-bearing retainer instability
- Degradation of thermal control surface in geo-synchronous orbit
- Slip-rings
- Bi-metallic thermal switches
- Polycarbonate capacitors
- Relays
- Electronic bond degradation ("purple plague")

---

* Drawn from Comments on the Transition from the Technology Base to Production, E. Rechtin

is shaved. The high quality product cannot compete in a cost manufacturing bidding contest. Yet, ironically, high-quality systems, like spacecraft, comprised of thousands of piece parts, are less costly to build and operate than those of low quality.

5. Problems of Mechanics and Timing of the Transition Process

Transition time and overall program costs cannot be reduced by reducing engineering development. Delayed engineering results in increased program cost and larger transition time, as illustrated in Table IV-3.

In some programs, the transition to production is complicated by the disruption of the normal process of research, then exploratory development, then advanced development, then engineering development, then preproduction and production. Sometimes phases like advanced development or engineering development are omitted altogether because of budgeting or time constraints. Sometimes gaps appear in the process so that the project grinds to a halt temporarily (with subsequent disruption of personnel and production scheduling).

Table IV-4 illustrates how a successful program was carried through -- the ground TOW missile program. This program was characterized by the following important factors: the U.S. Government was committed to the program; all of the transition steps were included; and there was continuity of funding and manpower.

6. Impact of Decision Making Process Complexity

A significant deterrent to innovation is the complexity of the decision-making process. Experience within space systems has shown the following functional relationship between the time to gain approval for a certain proposal and the number of approving signatures required:

$$\text{Time (Days)} = 2^{n-2}$$

n = number of approval signatures

[Ref: Rechtin, E.; Comments on the Transition from the Technology Base to Production; DSB Summer Study; August 1981]

D. TEST MARKETING: A NEW APPROACH

The DoD maintains a vigorous program in supporting new ideas and technology programs but does not plan adequately for the transition of maturing technology. There is a gap in planning and support to insure maturing technology programs are adequately funded and supported through the final critical phases of adequate demonstration prior to becoming candidates for FSED. This is caused by differences of opinion or what level of risks still remain in using the new technology. Other considerations include the large investment associated with such demonstrations and other competing new ideas that require funding.

TABLE IV-3

DELAYED ENGINEERING RESULTS IN INCREASED PROGRAM COST AND LONGER TRANSITION TIME

HUGHES

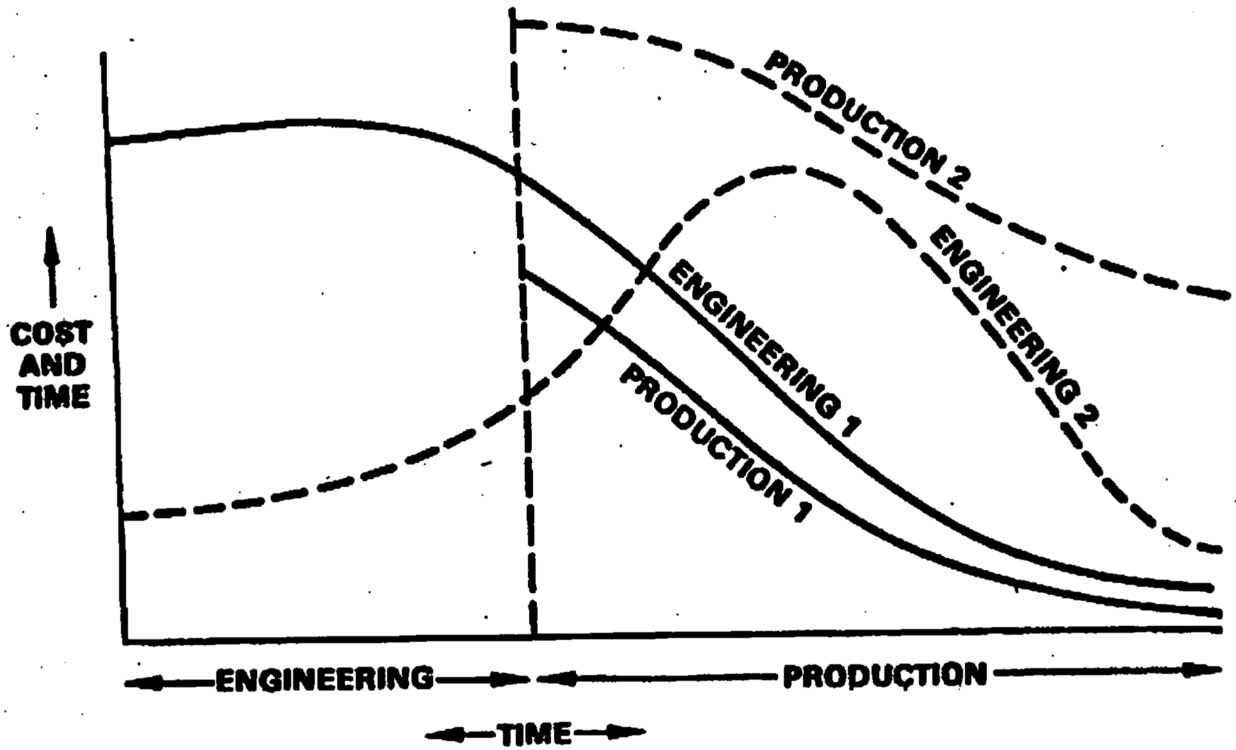
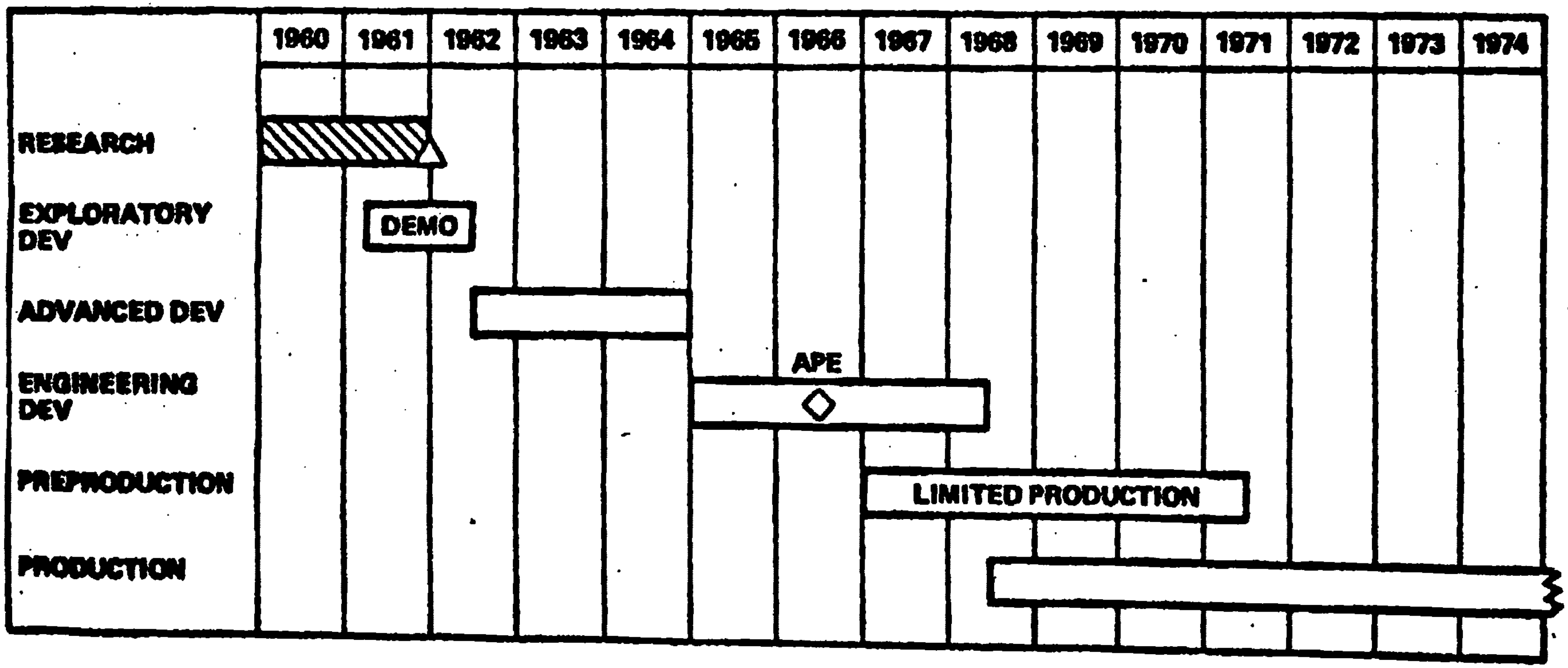


TABLE IV-4

GROUND TOW MISSILE PROGRAM

HUGHES



AUGUST 7, 1981

Before the new product developer will utilize a new technology, the risks must be judged reasonable, requiring a thorough demonstration of the new technology in the real environment. The DoD needs to recognize this essential step to risk reduction, payoff, and cost assessment prior to FSED and production. Not enough resources and programs are allocated to the final and necessary step of transition to new technology.

Another technique for enhancing technology transition is a "test market" approach. This approach would allow technology base developed hardware to be placed in operational or test unit for use and evaluation. This testing would provide direct feedback on equipment performance and allow the user to evaluate equipment utility and future need. This technique would enhance the communication between the user (both operators and trainers) and technology developers on characteristics and usefulness of equipment. It would also remove uncertainty in the requirement and technical approach during decisions for new systems.

E. SUMMARY

In summary the characteristics of successful transition are:

- Clear user definition of requirement
- Customer acceptance and strong sponsorship
- Customer participation in selection of technologies to be implemented
- Clear developer evidence that technology is ready and able to satisfy requirement
- Technology developments are clearly <u>needed</u> by user.

These conditions do not exist within the DoD transition process. Within the DoD, the following are barriers to the transition of technology into operational systems:

- Partitioning the research, development, and production process into separate organizations and contractors
- Lack of involvement of potential users in the establishment of requirements and the resulting programs
- Lack of fenced budgets to allow the product activities to fund transition of desired technology
- The failure to meet an "opportunity window"
- The lack of a risk/reward system
- Existence of a mature hardware option.

The DoD, as a total institution, does not address well the political nature of this process (e.g., bargaining, negotiation). Further, DoD does not plan sufficiently for success (e.g., few "technology insertion" plans developed along with major weapons systems). There is very little emphasis on technology demonstrations which accurately portray risk reduction, payoff, cost offset, and later stage production. The system has little incentive to exploit or respond to new technological capabilities. The organization and spatial separation of technical and systems people inhibit transition. Discontinuity of funding, indecision and the short-term orientation of many key decision authorities heighten this problem.

CHAPTER V

THE UNIVERSITY CONNECTION

CHAPTER V

THE UNIVERSITY CONNECTION

There exists a long history of DoD-university interaction. It was given a strong thrust by the Office of Naval Research (ONR) in the post-World War II period during which time research endeavors in university departments working in areas of general and specific national security interest were supported. These interactions expanded with participation by all Services. The post-Sputnik era provided another thrust with its emphasis on technology and the need for scientists and engineers. The relationship was seriously eroded during the Vietnam era, and, although the environment for coopertative undertakings is much improved today, its past history and inflation have been factors inhibiting realization of significant improvement. The opportunity for strengthing the university connection is present today; the DoD needs to make use of university resources that can contribute to our national defense posture; the universities need the DoD to assist in enhancing their capabilities in both education and research.

What the DoD needs and expects from universities

The DoD relies on the universities almost exclusively for trained scientists and engineers at the bachelor and graduate levels. The source of such personnel for the DoD itself, both civilian and military, for the defense industry and for future university staff is the universities.

In a second broad category, university faculty meet a DoD need as performers of research, thus giving rise to new ideas and results, for expert consultants on DoD projects and as a source of independent advice.

All of the needs will be better served by top-flight faculty and students in areas pertinent to national security needs. The universities thus need to be able to hire and retain such faculty, to have them engaged in significant forefront research in the more advanced fields of science and engineering, and to provide them with equipment, facilities, and support necessary to be productive. Both incentives and support are required. At the same time the DoD must recognize the university mode of operation, its policies and processes that, over time, have proven successful in carrying out educational activities and on-campus research.

Present Status

President Edward J. Bloustein of Rutgers University, in Congressional testimony approved by the American Council of Education, the Association of American Universities, and the National Association of State Universities and landgrant colleges, stated:

> ".....it is our sense that the university research base for defense preparedness is in some considerable disrepair. In particular, we are concerned that the national expenditures

for research have decreased markedly in recent decades; that there is a serious shortage of trained research personnel; that our research equipment and facilities is in a deplorable state of inadequacy; and that federal support for foreign language and international studies is totally incommensurate with our nation's needs."*

Three other university presidents and one industrial representative elaborated on these issues.

Findings

The Panel focused its attention on major items that in its opinion could make a difference in increasing the contributions to the nation's security through greater university involvement with DoD. The Report of the 1976 DSB Summer Study on Fundamental Research in Universities (see Appendix B, Item K) noted that a major source for new innovative ideas for future defense needs resides in the university community and urged that DoD reestablish and stimulate its relationship with that community. The conclusions of that study remain generally valid and were not reassessed in detail.

If current trends persist, the DoD and the country face a crisis in availability of technical personnel. There are several factors involved, starting at the secondary school level and extending to market place pressures for employment. More specifically, these factors include motivation, academic preparation and future job satisfaction including remuneration. The crisis is most apparent in the universities themselves and the DoD. While the supply of trained personnel is reasonably matched in most fields, there are critical shortages in the most advanced technologies such as electro-optics and computer sciences.

A further disturbing factor is the decreasing output of U.S. citizen doctoral graduates. The total number of doctoral degrees awarded annually in engineering has decreased about 25% in the past decade; at the same time the fraction of foreign nationals has increased from about 25% to almost 50% (see Figure V-1). This has substantially reduced the pool of graduates able to participate in sensitive DoD R&D.

Over the long run the universities and DoD will have to respond to market pressures in upgrading their science and engineering staffs. However, many top flight individuals respond favorably to opportunity and environment. The DoD can assist the universities significantly in creating better research environments through provision of greater R&D opportunities, upgraded on-campus equipment, and simplified policies and procedures for execution of on-campus R&D.

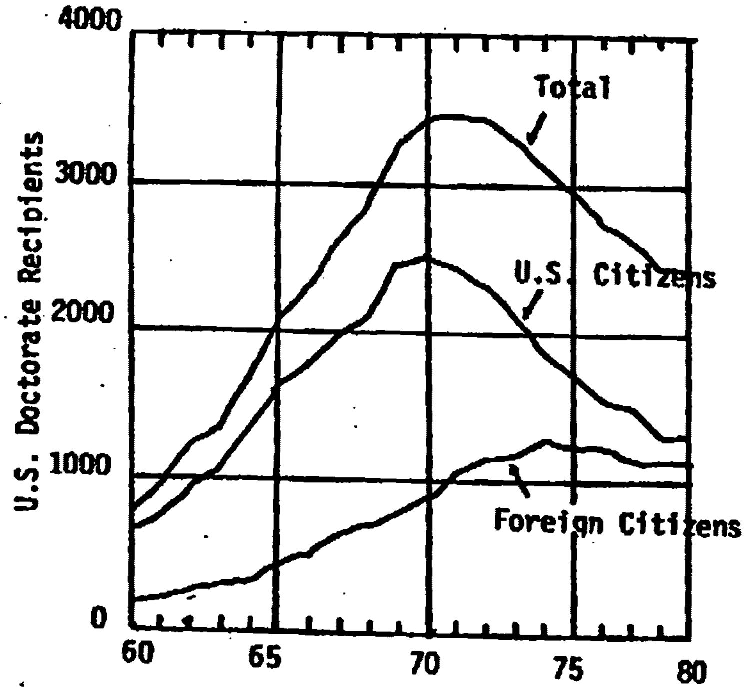
While it concentrated on science and technology, the Panel was alerted to the fact that training in the certain aspects of the social sciences (human interfaces, training) and in foreign languages (intelligence, interactions with allies and others) is an area of DoD interest that also needs support.

---

* Reference: Testimony by Edward J. Bloustein before the House of Representatives Armed Services Committee, Subcommittee on Research and Development, April 3, 1981.

FIGURE V-1

NUMBER OF U.S. ENGINEERING DOCTORATE RECIPIENTS



The DoD can not alone solve national problems. Deficiencies in support by other agencies of related programs, however, have an impact on DoD, and DoD should lend its support to those agencies for the common good. For example*, from 1968 to 1980 in the U.S.:

- R&D as a fraction of the federal budget decreased 36%.
- R&D as a fraction of the GNP decreased 19%.
- Scientists and Engineers engaged in R&D as a fraction of the labor force decreased 9%.

Contrast the above with other nations:

- U.S. R&D as a fraction of GNP dropped 19%, while it went up 14% in the Soviet Union, 16% in the Federal Republic of Germany, and 19% in Japan.

- U.S. scientists and engineers engaged in R&D as a fraction of the labor force dropped 9%, while it went up 62% in the Soviet Union, 75% in F.R.G. and 70% in Japan.

It is incumbent on all agencies of government to help rectify these trends.

The Panel's recommendations have focused on encouraging DoD to renew its commitment to basic research in the universities and at the same time to clearly enunciate its needs and R&D priorities. In doing so it must also recognize the needs of the universities and continue to work with them to seek mutually satisfactory arrangements in such diverse areas as:

- Stimulating increased enrollments and quality of students in fields of DoD priorities.

- Implementing mutually satisfactory controls on the export of information relating to munitions' list technologies.

- Seeking simplified and more appropriate contracting, reporting and auditing policies and procedures.

The greatest impact will, of course, result from increased funding and opportunities for R&D for faculty and graduate students. This funding stimulus is directed principally at DoD priority R&D activities, at equipment acquisition, and at graduate fellowships. Specifically, the Panel recommends a 25% increase (real growth) in 6.1 funding of research in universities over a three-year period. The rationale is simple: the opportunities and needs would undoubtedly support a larger increase; however, orderly, well thought out programs in basic research tend to be limited to growths of around 10% per year. Furthermore, a growth program should be reviewed periodically and three years is an appropriate interval.

---

* Reference: Testimony by Richard Atkinson before the House of Representatives Armed Services Committee, Subcommittee on Research and Development, April 3, 1981.

University testimony before Congress has indicated annual equipment needs equal to 25% of related R&D funds. The Panel strongly supports the need for modern, upgraded equipment in the universities. It has been noted that the average age of research equipment in universities is approximately twice that of industry, a factor that not only makes university researchers less competitive but also results in a deficiency in graduate student training. The Panel has not selected a dollar or a percentage figure; rather, it prefers to emphasize a thrust that will provide equipment that can make a major difference, one that will have high leverage or that will serve multiple interests. This does not exclude acquisition of general, or specialized equipment for specific projects but reflects priority. DoD should be encouraged to support strongly NSF in its program of upgrading university equipment and general facility capability. Computer resources are of the highest priority based on this algorithm.

Strengthening the university-industry interaction in R&D programs of DoD interest will benefit all three parties - DoD, industry, and the universities. Several incentives are possible to encourage industry to obtain both specific "products" from the universities and to "invest" in their futures. The Panel recommends that industry be encouraged to support work at universities through the IR&D route. Specifically, DoD should authorize an addition of 0.5% to the negotiated base against which IR&D ceilings are established for each contractor.

Concern was expressed that certain DoD procurement policies make life difficult for universities, particularly the treatment of indirect costs. Although OMB circular A-21 defines standards for accounting for indirect costs, there are differences between agencies. The U.S. Department of Health and Human Science (H&HS) systems for treatment of indirect costs was suggested as an easier system under which universities can operate. The H&HS concept is to calculate indirect costs centrally, thus removing the requirements for negotiation on each individual grant. After approval of the indirect cost package, the grantee institution will receive grand awards showing only direct costs. In general a simplified, research procurement process is important to facilitate university participation (e.g., the "short form" contract developed by ONR).

DoD could foster a stronger relationship with the universities by reestablishing and strengthening support for research and training in the fundamental sciences, through scholarships, traineeships and fellowships to graduate students and by support to the faculty through equipment grants. There was also concern that the statutory controls over the export of critical military technology could strain the DoD-university relationship. DoD must take the initiative to define and implement mutually satisfactory measures to accommodate both DoD and university needs.

Finally, the DoD has been charged by the House Armed Services Committee with preparing a report on "University Responsiveness to National Security Requirement." The present Technology Base Summer Study has touched on only a few of the topics that must be addressed in the response to HASC. The Panel recommends that DSB be requested to establish a Task Force to carry out the more comprehensive study. It is anticipated that the pertinent recommendations contained in this Panel's report would be seriously considered.

CHAPTER VI

DoD LABORATORIES AND DARPA

CHAPTER VI

DOD LABORATORIES AND DARPA

By way of preface, the members of the DSB Technology Base Panel want to affirm, at the outset, the vital role played by the DoD laboratories in maintaining a lead in critical military technologies and in achieving qualitative arms superiority over the Soviet Union. It is critical that DoD maintain a high level of competence, expertise, and dedication within its laboratory community. The Board also recognizes, however, the problems that have plagued the laboratories for a number of years and have underscored in this report what it collectively views as the most pressing requirements for enhancing the status, productivity, and output of the laboratories.

The DoD laboratories have been studied a number of times. Each study has provided sound recommendations which by and large have not been implemented (see Appendix H). The lack of effective response has led to a heightening of the problems in the laboratory base. The many bureaucratic restrictions (some by DoD, others Congressional) imposed on the laboratories have led to an inability to compete effectively in the job marketplace for young, highly qualified engineers and an increasingly older work force in the laboratory structure. The average age of scientific and engineering personnel now stands at 44. It is likely that this work force has not been able to remain completely current with today's state-of-the-art technology.

Attempts to circumvent these problems by raising grade levels and increasing pay have only led to inflated position descriptions and cost and have not really addressed the root causes. What is needed is a revolutionary change in personnel management policies concurrent with new and innovative research and development thrusts. The technology base must be tied to DoD needs and mission requirements as opposed to what one individual or group wants to do or has the skill to do. If the R&D is not needed, it should not be done.

Laboratory effectiveness and productivity are closely associated not only with the quality of the scientist/engineer, but also the flexibility of the budget and procurement processes. The procurement process is negatively impacting the effectiveness and productivity of DoD laboratories. In fact, the procurement process is driving many customers, particularly small businesses, away from our laboratories. What is needed is recognition that the present procurement methods are not cost effective (it requires 200 plus days to process $200,000.00 contracts). The problem is critical since 80 percent of Air Force laboratory contracts are less than $500,000.00. A revision of the DAR is needed to enable the necessary changes allowing contracts up to $500,000.00 to be processed within 90 days (e.g., with a short contract form).

Two important programs are now underway which may positively impact the DoD laboratory situation. These are: 1) the ongoing activity establishment of the DoD Laboratory Management Task Force which includes participation by OSD and the Military Departments, and, 2) personnel experiments in the management of scientific and engineering personnel being conducted at NOSC and NWC.

A. LABORATORY MANAGEMENT TASK FORCE

The Laboratory Management Task Force (LMTF) was set up following the 1978 Laboratory Directors Conference where concern was expressed over the alarming deterioration in the laboratories. The LMTF has issued two reports and has already made some important recommendations.

Past studies have found that although the laboratories are vital to defense R&DA, their contribution is seriously constrained by inhibiting internal procedures, inadequate pay for staff (particularly in highly competitive areas of science and technology), aging facilities, and mismatch of workload and manpower. These studies have recommended, in general, more flexibility and authority for the laboratory leadership, better facilities and staff, with particular emphasis on the quality of technical leadership and management.

Some positive actions have occurred but the continuing trend is downward, fueled by constraints on resources, the shortage of qualified scientists and engineers, and, finally, the weakening of management authority by civil service procedures and the layered decision-making structure within DoD.

The in-house laboratory effort is mammoth:

- 73 Laboratories -- all service-managed
- 60,000 people -- 80% civilian (Medical and Air Force laboratories -50% civilian)
- \$5.2 billion annual program -- 40% in-house overall (\$3 billion RDT&E effort with 50% in-house)
- Physical investment \$4 billion (50/50 real property/equipment)
- Small and large (some with fewer than 100 professionals and some with greater than 4000)
- Physical science, life science, and personnel R&D
- Activity spanning from basic research through the full RDT&E spectrum

Nearly two-thirds of the annual cash flow is RDT&E money. About one-half of the R&D funds are contracted to universities and industry; the other half is retained by the laboratories to carry out roles requiring in-house personnel, including extensive activities necessary to monitor and support contract work.

DoD laboratories are supposed to provide in-house functions which are not easily obtained from outside sources, namely:

- To maintain technical expertise to identify, evaluate, and exploit new technology, and to avoid technical surprises.

- To support DoD as a sophisticated buyer and monitor for contracts, and to provide system support.

- To provide a corporate technical memory and undertake activities having extraordinary risk or requiring quick reaction.

The LMTF found that there were significant barriers to performing these roles due to inadequacy in management, staff, facilities, and equipment and has made very specific recommendations concerning: personnel and manpower, facilities and equipment, procurement and acquisition (see Appendix H).

In summary, the DSB Summer Study Panel has found that previous studies including the LMTF study have identified important areas of deficiency but corrective advice is not often heeded. The present DoD laboratory base is fragmented and duplicative in key area, e.g., computer science, software, very large-scale integrated (VLSI) circuits, and signal processing. Further, too often the technology base is pursued for its own sake and not in response to mission needs. Finally, the panel recognizes that personnel problems are acute and that grade raising or pay increases without other reforms will not provide the cure.

B. NOSC/NWC DEMONSTRATION PROJECT

NOSC and NWC established demonstration projects in 1980 under the Civil Service Reform Act aimed at achieving a more responsive and flexible personnel system. On July 13, 1980 all scientists, engineers, and technical specialists as well as all other GS 13-15 employees were converted from their present positions to comparable ones under the experimental system. Appendix F provides a more detailed description of this project.

The demonstration project, as approved by the Office of Personnel Management, waives a number of existing federal personnel regulations in these areas and substitutes revisions geared to the experimental system. The new approach simplifies the classification system, implements an appraisal process linking pay and performance, and provides a mechanism for recognizing performance as the primary criterion of retention (see Appendix F for details). Table VI-1 is an illustration of the new scheme.

This demonstration project allows employees the opportunity to advance their careers at a faster pace than under the existing system. Another important feature is that it recognizes dual career ladders, such that technical personnel may continue working in their specific discipline if they wish rather than being forced into management for advancement.

The Incentive Pay System (IPS) within this demonstration project is designed to reward high performances, provide in-level salary growth as people mature, and deny pay increases to low performers. Employees who meet performance objectives will parallel the General Schedule (GS) pay system, but higher performers will receive positive incentives through continuing salary increases. This differs significantly from the traditional GS pay system where pay increases within each grade are largely a function of seniority.

The pay formula has been developed to provide meaningful incentive pay to high performers by redistributing funds obtained from either grade increases, merit awards, and in-level promotions. Money not awarded to low performers (B or N on Figure IV-1) will be included in the center's paypool. Employees rated M (met objectives) will rapidly achieve the midpoint salary level which is comparable to salaries paid in industry. To receive a salary increase above industry equivalency, an employee would be expected to demonstrate superior performance and receive ratings of E and O.

The new system is expected to enhance recruitment of quality personnel and aid in retention. High performers advance by performance appraisal and promotions between levels while low performers incrementally retreat through performance appraisal process to level of competence/actual performance. This could eliminate some high grade alignment problems and reduce problems with GS level prestige.

The demonstration project will be evaluated internally at NOSC and NWC by members of the faculty at the School of Public Administration, University of Southern California. Detailed evaluation results are not yet available.

The DSB panel was impressed by the nature and scope of the NOSC/NWC personnel experiment and recommends that this plan or its equivalent be seriously considered for all DoD laboratories in order to recruit, hire, motivate, and retain quality scientists and engineers. Panel members felt that the most exciting features of this experiment were:

- Greater latitude in job classification
- Reduced level of paperwork, more flexibility and potential for faster decision-making
- A focus on performance as the foremost criterion for salary increases, promotion, and retention.

C. DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)

As with the DoD laboratory base, the state of DARPA was a recurring issue of discussion. The DSB panel believes that the DARPA technology base program has exceeded the size which can be effectively managed by the relatively small DARPA staff. An adversary relationship has developed between DARPA and the Services because:

- DARPA competes with Services for technology base funds; and
- Large DARPA technology programs are not well-coordinated with Service objectives and plans.

There appears to be no comprehensive filtering of DARPA programs and the DARPA results are not widely disseminated or sufficiently critiqued. In addition, the growth of the large technology demonstration efforts within DARPA in recent years has hurt the ability of DARPA to react vigorously to new ideas in the exploratory technology arena.

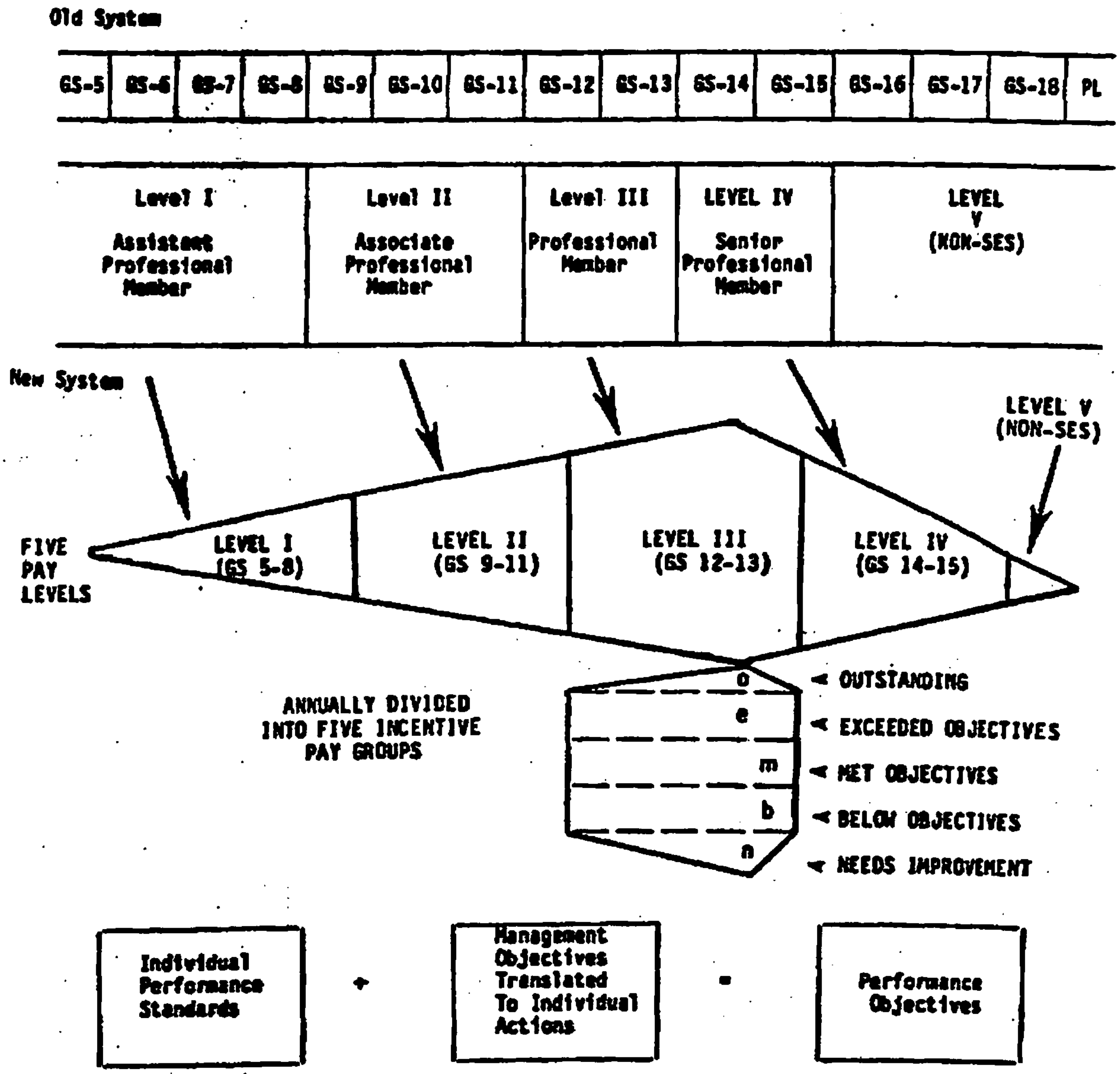
While such large technology demonstrations may be necessary because of the cross-service mission areas involved, a method must be developed for ensuring that the important DARPA flexibility in exploratory development can be preserved. The current problem is that with both major demonstrations and smaller exploratory programs managed out of the same office, program expansion and overruns by the demonstration programs can too easily claim funding originally planned for a balanced exploratory development program.

The Ballistic Missile Defense Advanced Technology Center (BMDATC) and Advanced Ballistic Re-Entry Systems (ABRES) technology base programs have suffered the same problem as those of DARPA. Expansion of demonstration programs within a constrained budget has forced major cutback in the longer range technology programs. There are some areas where BMDATC has a strong position, in particular, software and architecture for real-time data processing. Because their funding is 6.3 money, there is no formal mechanism for coordinating these activities with the rest of the DoD technology base programs.

TABLE VI-1

DEMONSTRATION PROJECT AT NOSC AND NWC

BASIC TECHNICAL PROFESSIONAL PAY LEVELS AND CLASSIFICATION LEVELS



- PERFORMANCE DIRECTLY AFFECTS PAY
- TRAINING AND CORRECTIVE ACTIONS INDENTIFIED
- REVIEWS AT 6-MONTH INTERVALS
- PAY ADJUSTED ANNUALLY

CHAPTER VII

SUMMARY - FINDINGS AND RECOMMENDATIONS

CHAPTER VII

SUMMARY - FINDINGS AND RECOMMENDATIONS

A. TECHNOLOGIES THAT COULD MAKE AN ORDER OF MAGNITUDE DIFFERENCE

1. Relating Scenarios and Technology Priority to Investment Decisions

Findings:

In reviewing the planning processes within the Services, there was no consistently applied linkage between scenarios, technical opportunities, and risks to investment decisions in the technology base. Further, there is no formalized prioritization process for technologies outside of that implicit in the technology base budget. In fact, the work of diverse elements of the Services often incorporates a different set of scenarios. The figure of merit method used herein was derived due to the lack of a uniform structured process within the Services.

Recommendations:

The USDRE allocate resources to the Services and all levels of the technology base on a consistent scenario-oriented basis.

- (U) Recognize organizational excellence by evaluation of the matching of resources and technology priorities with the scenarios.

The ASD(R&T) adapt a prioritization and investment strategy approach based on the figure of merit used in this study.

2. Investment Status - Underinvestment

Findings:

Based on a comparison of the technology evaluation herein with the current DoD investment, a number of "Order of Magnitude" technologies were identified which require more aggressive funding:

- Machine Intelligence
- Advanced Software/Fast Algorithms
- Short Wavelength Lasers
- Hardening of Advanced Electronics
- Microprocessor-Based Personal Learning Aids
- Fault Tolerant/Fail-Soft (Self-Policing) Electronics

Recommendations:

The ASD(R&T) increase funding in these areas (as outlined in Chapter II of this report.)

3. Investment Status - Overinvestment

Findings:

Although no effort was made to recommend specific programs which should be deleted, several categories of activity were highlighted for deemphasis:

- Areas of duplication with NASA (e.g., remote sensing, propulsion)
- Overexpansion of DARPA programs into areas which overlap with other major DoD/Service programs (e.g., forward swept wing, VLSI, fiber optics)
- Nonproductive duplication of the generic technology base by the three Services
- In-house execution of the basic research program (6.1).

Recommendations:

The ASD(R&T) undertake a thorough review of these areas with the goal of eliminating duplication and reducing investments in these areas.

4. Investment Strategy

Findings:

A review of the process by which each of the Services develops its investment strategy was conducted. Although each Service has a structured approach to technology base planning, there appears to be a failure to come to grips consistently with the full range of questions necessary to develop a well founded investment strategy "catechism":

- What is it? What is this effort trying to accomplish (defining the technology sufficiently well to discriminate it from other similar technologies)?
- Why is it important? Assuming success, what difference can it make to the user or in a mission area context (taking into account the nature and limitation of current practice)?
- What is the current status? What is the DoD program? What should it be? What is new about the proposed effort and why will this approach be successful?
- How long will it take? How much will it cost? What are the measures of success?

Recommendations:

The USDR&E should direct the military departments and DARPA to use this investment strategy "catechism" in all future technology base planning and POM guidance.

5. Management of the "Order of Magnitude" Technologies

Findings:

There is a diffusion of the DoD effort in many of "order of magnitude" technologies throughout DARPA and the Services. This diffusion appears to lead to many subcritical efforts without the impact of a more focused approach.

Recommendations:

The ASD (R&T) formulate vertically integrated technology base programs with fenced funding, similar to VHSIC in the following areas:

- Machine Intelligence
- Advanced Software/Algorithm Technology
- High Power Microwave
- Advanced Materials (Rapid Solidification Technology, Advanced Composities)
- Microprocessor-Based Personal Learning Aids

6. Overall Level of Funding of the Technology Base

Findings:

The overall level of funding in the technology base is assessed as being adequate. If properly organized and managed, 2% of the DoD budget (the current level) is probably adequate. This ideal cannot be achieved unless the decision making and allocation process within DoD is restructured to reflect the planning methodology outlined in this report.

Recommendations:

None

B. TECHNOLOGY TRANSITION

1. Barriers to Transition

Findings

The following barriers to the transition of technology into operational systems are highlighted:

- Partitioning the research, development, and production process into separate organizations and contractors
- Lack of involvement of potential users in the establishment of requirements and the resulting programs
- Lack of fenced budgets to allow the product activities to fund transition of desired technology
- The failure to meet an "opportunity window"
- The lack of a risk/reward system
- Existence of a mature hardware options

DoD, as a whole, does not adequately address these barriers. There is very little emphasis on technology demonstrations which accurately portray risk reduction, payoff and cost offset, and later stage production or to conduct "test marketing" experiments. The system has little incentive to exploit or respond to new technological capabilities. The organization and spatial separation of technical and systems people inhibit transition. Discontinuity of funding, indecision and the short term orientation of many key decision authorities heighten this problem. A champion on the user side is often not present.

Recommendations:

In order to better focus DoD resources on the transition issue that the USDRE direct the creation of an advanced projects agency charged as follows:

- To develop subsystem or system experiments to quantify the maturity (risk and cost of FSED) of emerging technology
- To conduct "test marketing" experiments
- To be populated by people in the Services

However, if a new agency is not formed, the DoD should not terminate DARPA activities in this area. The function is too important not to focus OSD attention on it. Also, the Services should fence a large 6.3A budget for conducting the needed demonstrations.

2. Technology insertion

Findings:

The DoD does not plan adequately for successful technology transition throughout the life of a system. Such plans are often injected only as an afterthought.

Recommendations:

The USDRE require technology insertion plans as a basic and fundamental part of program planning.

C. THE UNIVERSITY CONNECTION

Findings:

The universities and DoD need each other. DoD needs the scientists and engineers trained by the universities; it needs the faculty pool of scientists and engineers working in the DoD area as generators of new ideas and results, as expert consultants and as advisors. The university research base for defense preparedness is in considerable disrepair and therefore in need of upgrading in faculty, equipment, facilities and support. It is a problem broader than DoD, but DoD has a specific interest and responsibility.

Mechanisms are needed to stimulate quantity and quality in the training of scientists and engineers in defense-related subjects, especially in advanced technologies, to encourage their employment in the universities and DoD activities.

In the broader terms, the stimulation can be provided by increased support -- government and industry -- of R&D in the universities, by fellowships for graduate training in specialized fields, and by equipment acquisitions that will have an impact on research of high DoD leverage. In addition there are numerous DoD administrative policies and procedures that are detrimental to the ability of the universities to carry out these activities and need mutual discussion and resolution, for example, export controls on information and the DoD procurement process.

Finally, the DoD must respond to the House Armed Services Committee for a study on "University Responsiveness to National Security Requirements." The DoD response will require greater in-depth study than was provided by this DSB Panel.

Recommendations:

Based on these findings, the following recommendations were made:

1. The USDRE direct the services to increase 6.1 basic research performed by universities by 25% in real growth over the next three years.

2. USDRE authorize each of the services to award 100 S&E graduate fellowships annually.

- In areas of DoD interest - similar to those of the DoD laboratories.

- $20K/year to continue until completion of degree but not to exceed 3 years (part to students and part to university)

- Competitive -- awarded by Congressmen

- Must work one year in DoD lab for each year of fellowship support granted

3. The USDRE direct the DAR Committee to revise current procurement policies and regulations to allow:

   - Additional IR&D -- 0.5% against negotiated base over present ceiling -- for industry support of university R&D

   - Treatment of university indirect costs similar to that used by U.S. Dept of Health and Human Services (HHS)

   - Simplification of research procurement from universities

4. The USDRE establish with the universities an accommodation and basis for the implementation of current export controls on information relating to munitions list technologies.

5. The ASD(R&T) direct the services to create a DoD thrust via the OSR's to upgrade equipment in universities. This focus should be on equipment that can impact university research of highest DoD leverage (software, design automation, machine intelligence, etc.)

   - The upgrading of computer resources is the highest priority based on this algorithm.

   - Generally, DoD should support NSF efforts to upgrade equipment in universities.

D. GENERAL FINDINGS AND RECOMMENDATIONS

Findings

As a result of addressing the three previous questions (The "Order of Magnitude" Technologies, Technology Transition, and The University Connection), a number of recurring themes arose with regard to the state of DoD in-house laboratories, DoD S&E personnel, and DARPA.

The following findings draw themes together:

- DoD laboratory prospects for improvement are poor, given their current state and the constraints that afflict them. Of particular concern is the weak, fragmented and duplicative effort in key areas, e.g., computer science, machine intelligence, software, VSLI and signal processing.

- Over the years, there have been a number of studies by various groups of the DoD laboratories...good advice which is rarely heeded.

- There is an impending crisis in personnel and facilities in the DoD laboratories that will seriously degrade the defense posture in a very few years.

  - The average age of civilian S&E is 44 years.

  - Because of the inability to competitively hire highly qualified individuals at lower levels (GS5-7-9), the work force is continuing to age.

  - The primary skills of this aging work force are becoming outdated.

  - Because of attrition and personnel ceilings, the quality of personnel may be eroding.

  - Raising grade levels or increasing pay without other reforms will not solve these problems in the highest leverage areas.

- DARPA

  - The growth in the DARPA technology base program has greatly exceeded the capability of the staff to properly execute the program.

  - There appears to be no comprehensive filtering of DARPA programs versus on-going service efforts. Further DARPA results are not widely disseminated and therefore not sufficiently critiqued.

  - There is no clear, organizational division within DARPA of responsibility for the exploratory development programs (6.2) and large scale technology demonstrations (6.3A). In fact, the budgets for these two classes of R&D are often mixed.

Recommendations:

Based on these findings, the following recommendations were made:

1. To help the hiring and retention of the skills necessary for a viable laboratory structure, USDRE direct that the highly exciting and effective personnel experiment being conducted at NOSC and NWC or its equivalent be implemented for DoD laboratories. The most exciting features of this experiment are:

  - Reduces paperwork
  - Makes performance the foremost criteria for salary increases, retention, promotion, etc.
  - Enhances flexibility and allows faster decisions.

2. USDRE, in conjunction with Service technology base managers, designate lead laboratories in generic technology base areas within each Service. Candidate technology areas include:

- Space systems related technology (components, hardening, etc.)
- Airborne radar technology
- Airborne electronic warfare technology
- Electron devices
- Infrared technology

3. USDRE:

- direct that the Services review DARPA programs over $30M (total program costs -- not annual) from the point of view of potential future military applications, operational needs, and transition plans.
- establish a mechanism to ensure coordination of system technology base programs (such as BMDATC and ABRES) with the rest of the DoD technology base activity to ensure that multiple system requirements are included in the development of the technology base investment strategy.

APPENDIX A

DSB TECHNOLOGY BASE SUMMER STUDY
TERMS OF REFERENCE

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

RESEARCH AND ENGINEERING

2 JUL 1981

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Summer Study: Technology Base

You are requested to undertake a Summer Study to assess the health of the U.S. national defense technology base, within and outside the government. Estimates of Soviet military research and development show that the Soviets have steadily increased their outlays for military RDT&E over time, and are now spending roughly twice that of the United States. To date, the United States has maintained leadership in most of the basic technologies critical to defense, partly because of a focus on critical technology edge and the momentum in defense technology built up during the 1960s. However, it appears that the United States may be losing the lead in some key technologies.

The United States strategy for dealing with the Soviet military challenge is critically dependent on the effective defense exploitation of the broad based U.S. technology. This study should address the following questions:

1. What technologies are critical to future (1990-2000) defense capability? What are those technologies that would contribute to roughly an order of magnitude improvement in system performance, cost, etc.? How are these technologies identified? Are the Soviets gaining ground? Is the investment on the Technology Base of less than 2% of the total defense budget adequate? If not, what is a reasonable level of expenditure and what should be the management and investment strategy within the technology base?

2. Is the process of transition from technology base to weapon systems adequate? If not, what changes are needed to accelerate the process of transition?

3. Are the universities responsive to national security requirements? If not, what actions should be taken to improve the responsiveness of universities?

4. Is the DoD relationship with the basic research community, creative individuals and small innovative firms adequate? If not, what changes should be made to improve the DoD utilization of these resources?

5. Are the scientific/engineering personnel resources adequate to meet the requirements of the defense technology (commercial or government)? What actions should be taken to eliminate critical personnel shortages?

Items 3, 4, and 5 are to be considered provided sufficient time and resources are available to the Summer Study.

This Summer Study topic is sponsored by Dr. George P. Millburn, Acting Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology). Dr. George H. Heilmeier has agreed to serve as Chairman. The Executive Secretary will be Dr. Samuel A. Musa, OUSDRE/R&AT.

R. D. DeLauer

APPENDIX B

REVIEW OF PAST STUDIES

APPENDIX B

REVIEW OF PAST STUDIES RELATED TO THE DOD LABORATORY/UNIVERSITY ISSUE

1. Make the overall research strategy less vulnerable to changing environmental influences (e.g., Congressional mood swings)

Reports where these recommendations appeared: A., C., E., G., I., K., S.*

2. Improve communication/cooperation between DoD in-house laboratories and the general research community.

Reports where these recommendations appeared: C., D., E., G., H., J., K., M., S.

3. Shift the ratio of intramural to extramural research toward outside contracts and/or increase the percentage of university/small business basic research.

Reports where these recommendations appeared: B., C., F., K., M., T.

4. Increase block funding to basic research programs (both out-/in-house) in order to maximize innovation and permit flexibility.

Reports where these recommendations appeared: B., C., F., G., K., S. T.

5. Establish a review mechanism for university, contractor, and in-house research programs that bases further funding on the quality, productivity, and impact of the research.

Reports where these recommendations appeared: A., C., E., G., H., I., K., M., T.

6. Remove the "albatross" of relevancy from the necks of researchers (both intramural and extramural) in order to free scientists/engineers from the limiting effects of such constraints. Make the criteria of relevancy apply to broadly defined fields and disciplines rather than to an individual program area.

Reports where these recommendations appeared: C., D., G., H., K., M., T.

7. Overcome the "inertia to change" evident in some DoD in-house laboratories (which inhibits progress towards more advanced technologies) by simplifying the complicated, layered management structure.

Reports where these recommendations appeared: A., B., C., F., G., H., I. K., S., T.

*See key on second page for report references.

8. Enhance the quality of the research in in-house laboratories by improving the position of in-house scientific personnel:

- Make salary/benefits competitive with industry
- Make career options more promising/stable
- Do not subject quality technical personnel to the vagaries of budget management nor to the public disclaim accorded all civil service workers.

Reports where these recommendations appeared: A., C., E., H., I., J., L., T.

9. Avoid the trend toward over-burdened, overly comprehensive (full spectrum) in-house laboratories. Consolidate and focus the research and eliminate diversification at the laboratories and/or FCRC's.

Reports where these recommendations appeared: A., B., D., F., G., H., T.

10. Increase the amount and timeliness of DoD implementation of high quality, front-line, capital equipment at facilities (both out-/in-house).

Reports where these recommendations appeared: C., H., K., L.

KEY (The corresponding background summaries follow in the remainder of the appendix.)

A. Report of the Ad Hoc Committee on In-House Laboratories, Army Scientific Advisory Panel (ASAP), December 1963. (page B-4)

B. Management of Federal Contract Research Center, DDR&E, June 1976. (page B-6)

C. Proceedings of an AAAS Symposium on "How Much Does the Defense Department Advance Science?" January 1980. (page B-7)

D. Required In-House Capabilities for DoD Research, Development, Test, and Evaluation, OUSDRE, October 1980. (page B-9)

E. Ad Hoc Group on Scientific Personnel, ASAP, April 1964. (page B-11)

F. Report of the DSB Task Force on Technology Base Strategy, October 1976. (page B-13)

G. Report of the Panel on Research and Exploratory Development, DSB-NBS, July 1967. (page B-16)

H. Report of the Science Advisor's Panel on Basic Research in the Department of Defense, OSTP, June 1978. (page B-18)

I. Historical Perspectives in Long-Range Planning in the Navy, NRAC Study, September 1980. (page B-19)

J. Technology Planning for Future Fielded Systems, Army Science Board 1979 Summer Study, July 1980. (page B-21)

K. Fundamental Research in Universities, DSB Summer Study, October 1976. (page B-22)

L. Man-Machine Technology in the Navy, NRAC Study, December 1980. (page B-24)

M. DoD Small Business Advanced Technology Program, DESAT, 1981-82. (page B-26)

N. Look Forward 20 Years, Volume I, AFSC, March 1980. (page B-31)

O. Ad Hoc Review of the 1974 Army Summer Study Review, ASAP, October 1975. (page B-33)

P. Army Scientific Panel Summer Study, 1974. (page B-36)

Q. Army Science Advisory Board Summer Study, 6 Volumes, 1976. (page B-37)

R. Army/Air Force Joint Summer Study, U.S. Air Force Academy, 1976. (page B-47)

S. Project Hindsight, ODDRE, October 1969. (page B-53)

T. DoD Laboratory Utilization Study, 1975. (page B-55)

REPORT ON THE AD HOC COMMITTEE ON IN-HOUSE LABORATORIES

ARMY SCIENTIFIC ADVISORY PANEL DECEMBER 1963

Goals

(1) To strengthen the Army in-house research and exploratory development activities by analyzing funding to the Army laboratories. How can Army labs be provided with the resources necessary to carry-out sound, long range research programs?

(2) To identify and analyze problems related to funding, including organization, research, objectives, personnel, and facilities.

Methodology

The study utilized interviews and/or questionnaires to obtain first-hand data from Army in-house personnel. They also gathered fiscal data, mission statements, and utilized other studies as supporting documentation.

Results

The panel results fall into two major areas:

(1) Those relating to planning, organizing, and controlling the effort.

(2) Those relating to proper allocation of funds to ensure maximum efficiency and produce R&D results that warrant annual investment.

Recommendations

(1) Reassess the long-term research-exploratory development objectives (and plans) in order to identify broad areas of technical interest to future Army mission needs.

(2) Redefine and clarify the Army mission, especially that of its laboratories, in light of other Service missions and RDT&E.

(3) Reorganize and toughen Army RDT&E management to prevent division of 6.1/6.2 funds or reprogramming of funds within 6.1/6.2 away from important areas.

(4) Make 6.1/6.2 budget arguments less vulnerable to changes in funding methods and congressional mood swings. Protect research freedom.

(5) Stress the importance of consolidation of those labs producing state-of-the-art, front-line research.

(6) Ensure that Army RDT and management and ASA(R&D) are involved where any budget, diversion, or reprogramming of funds (greater than twenty percent) is suggested for the 6.1/6.2 budgets.

CHAPTER VI

DOD LABORATORIES AND DARPA

By way of preface, the members of the DSB Technology Base Panel want to affirm, at the outset, the vital role played by the DoD laboratories in maintaining a lead in critical military technologies and in achieving qualitative arms superiority over the Soviet Union. It is critical that DoD maintain a high level of competence, expertise, and dedication within its laboratory community. The Board also recognizes, however, the problems that have plagued the laboratories for a number of years and have underscored in this report what it collectively views as the most pressing requirements for enhancing the status, productivity, and output of the laboratories.

The DoD laboratories have been studied a number of times. Each study has provided sound recommendations which by and large have not been implemented (see Appendix H). The lack of effective response has led to a heightening of the problems in the laboratory base. The many bureaucratic restrictions (some by DoD, others Congressional) imposed on the laboratories have led to an inability to compete effectively in the job marketplace for young, highly qualified engineers and an increasingly older work force in the laboratory structure. The average age of scientific and engineering personnel now stands at 44. It is likely that this work force has not been able to remain completely current with today's state-of-the-art technology.

Attempts to circumvent these problems by raising grade levels and increasing pay have only led to inflated position descriptions and cost and have not really addressed the root causes. What is needed is a revolutionary change in personnel management policies concurrent with new and innovative research and development thrusts. The technology base must be tied to DoD needs and mission requirements as opposed to what one individual or group wants to do or has the skill to do. If the R&D is not needed, it should not be done.

Laboratory effectiveness and productivity are closely associated not only with the quality of the scientist/engineer, but also the flexibility of the budget and procurement processes. The procurement process is negatively impacting the effectiveness and productivity of DoD laboratories. In fact, the procurement process is driving many customers, particularly small businesses, away from our laboratories. What is needed is recognition that the present procurement methods are not cost effective (it requires 200 plus days to process $200,000.00 contracts). The problem is critical since 80 percent of Air Force laboratory contracts are less than $500,000.00. A revision of the DAR is needed to enable the necessary changes allowing contracts up to $500,000.00 to be processed within 90 days (e.g., with a short contract form).

Two important programs are now underway which may positively impact the DoD laboratory situation. These are: 1) the ongoing activity establishment of the DoD Laboratory Management Task Force which includes participation by OSD and the Military Departments, and, 2) personnel experiments in the management of scientific and engineering personnel being conducted at NOSC and NWC.

A. LABORATORY MANAGEMENT TASK FORCE

The Laboratory Management Task Force (LMTF) was set up following the 1978 Laboratory Directors Conference where concern was expressed over the alarming deterioration in the laboratories. The LMTF has issued two reports and has already made some important recommendations.

Past studies have found that although the laboratories are vital to defense R&DA, their contribution is seriously constrained by inhibiting internal procedures, inadequate pay for staff (particularly in highly competitive areas of science and technology), aging facilities, and mismatch of workload and manpower. These studies have recommended, in general, more flexibility and authority for the laboratory leadership, better facilities and staff, with particular emphasis on the quality of technical leadership and management.

Some positive actions have occurred but the continuing trend is downward, fueled by constraints on resources, the shortage of qualified scientists and engineers, and, finally, the weakening of management authority by civil service procedures and the layered decision-making structure within DoD.

The in-house laboratory effort is mammoth:

- 73 Laboratories -- all service-managed
- 60,000 people -- 80% civilian (Medical and Air Force laboratories -50% civilian)
- $5.2 billion annual program -- 40% in-house overall ($3 billion RDT&E effort with 50% in-house)
- Physical investment $4 billion (50/50 real property/ equipment)
- Small and large (some with fewer than 100 professionals and some with greater than 4000)
- Physical science, life science, and personnel R&D
- Activity spanning from basic research through the full RDT&E spectrum

Nearly two-thirds of the annual cash flow is RDT&E money. About one-half of the R&D funds are contracted to universities and industry; the other half is retained by the laboratories to carry out roles requiring in-house personnel, including extensive activities necessary to monitor and support contract work.

DoD laboratories are supposed to provide in-house functions which are not easily obtained from outside sources, namely:

- To maintain technical expertise to identify, evaluate, and exploit new technology, and to avoid technical surprises.

- To support DoD as a sophisticated buyer and monitor for contracts, and to provide system support.

- To provide a corporate technical memory and undertake activities having extraordinary risk or requiring quick reaction.

The LMTF found that there were significant barriers to performing these roles due to inadequacy in management, staff, facilities, and equipment and has made very specific recommendations concerning: personnel and manpower, facilities and equipment, procurement and acquisition (see Appendix H).

In summary, the DSB Summer Study Panel has found that previous studies including the LMTF study have identified important areas of deficiency but corrective advice is not often heeded. The present DoD laboratory base is fragmented and duplicative in key area, e.g., computer science, software, very large-scale integrated (VLSI) circuits, and signal processing. Further, too often the technology base is pursued for its own sake and not in response to mission needs. Finally, the panel recognizes that personnel problems are acute and that grade raising or pay increases without other reforms will not provide the cure.

B. NOSC/NWC DEMONSTRATION PROJECT

NOSC and NWC established demonstration projects in 1980 under the Civil Service Reform Act aimed at achieving a more responsive and flexible personnel system. On July 13, 1980 all scientists, engineers, and technical specialists as well as all other GS 13-15 employees were converted from their present positions to comparable ones under the experimental system. Appendix F provides a more detailed description of this project.

The demonstration project, as approved by the Office of Personnel Management, waives a number of existing federal personnel regulations in these areas and substitutes revisions geared to the experimental system. The new approach simplifies the classification system, implements an appraisal process linking pay and performance, and provides a mechanism for recognizing performance as the primary criterion of retention (see Appendix F for details). Table VI-1 is an illustration of the new scheme.

This demonstration project allows employees the opportunity to advance their careers at a faster pace than under the existing system. Another important feature is that it recognizes dual career ladders, such that technical personnel may continue working in their specific discipline if they wish rather than being forced into management for advancement.

The Incentive Pay System (IPS) within this demonstration project is designed to reward high performances, provide in-level salary growth as people mature, and deny pay increases to low performers. Employees who meet performance objectives will parallel the General Schedule (GS) pay system, but higher performers will receive positive incentives through continuing salary increases. This differs significantly from the traditional GS pay system where pay increases within each grade are largely a function of seniority.

The pay formula has been developed to provide meaningful incentive pay to high performers by redistributing funds obtained from either grade increases, merit awards, and in-level promotions. Money not awarded to low performers (B or N on Figure IV-1) will be included in the center's paypool. Employees rated M (met objectives) will rapidly achieve the midpoint salary level which is comparable to salaries paid in industry. To receive a salary increase above industry equivalency, an employee would be expected to demonstrate superior performance and receive ratings of E and O.

The new system is expected to enhance recruitment of quality personnel and aid in retention. High performers advance by performance appraisal and promotions between levels while low performers incrementally retreat through performance appraisal process to level of competence/actual performance. This could eliminate some high grade alignment problems and reduce problems with GS level prestige.

The demonstration project will be evaluated internally at NOSC and NWC by members of the faculty at the School of Public Administration, University of Southern California. Detailed evaluation results are not yet available.

The DSB panel was impressed by the nature and scope of the NOSC/NWC personnel experiment and recommends that this plan or its equivalent be seriously considered for all DoD laboratories in order to recruit, hire, motivate, and retain quality scientists and engineers. Panel members felt that the most exciting features of this experiment were:

- Greater latitude in job classification
- Reduced level of paperwork, more flexibility and potential for faster decision-making
- A focus on performance as the foremost criterion for salary increases, promotion, and retention.

C. DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)

As with the DoD laboratory base, the state of DARPA was a recurring issue of discussion. The DSB panel believes that the DARPA technology base program has exceeded the size which can be effectively managed by the relatively small DARPA staff. An adversary relationship has developed between DARPA and the Services because:

- DARPA competes with Services for technology base funds; and
- Large DARPA technology programs are not well-coordinated with Service objectives and plans.

There appears to be no comprehensive filtering of DARPA programs and the DARPA results are not widely disseminated or sufficiently critiqued. In addition, the growth of the large technology demonstration efforts within DARPA in recent years has hurt the ability of DARPA to react vigorously to new ideas in the exploratory technology arena.

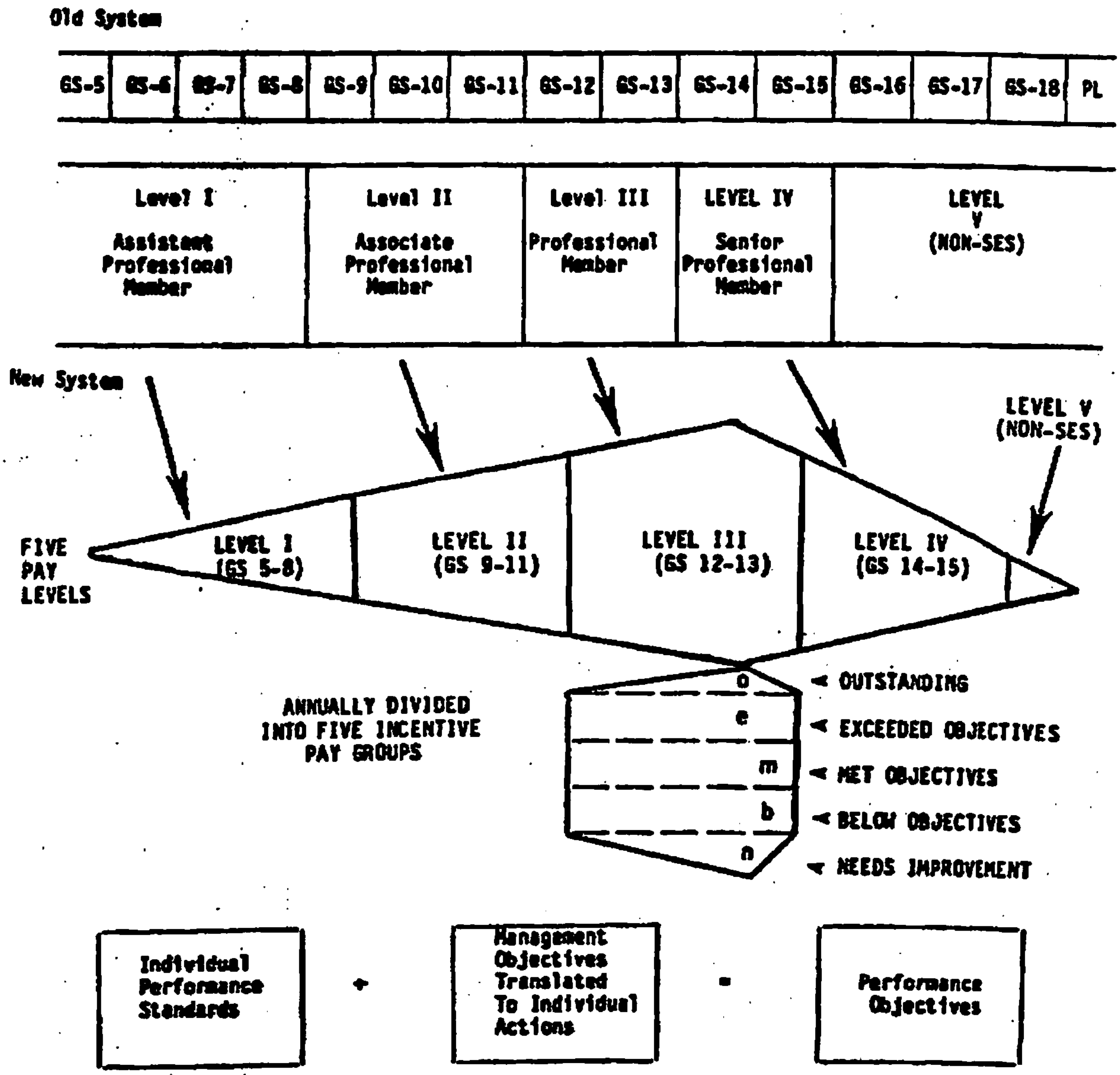
While such large technology demonstrations may be necessary because of the cross-service mission areas involved, a method must be developed for ensuring that the important DARPA flexibility in exploratory development can be preserved. The current problem is that with both major demonstrations and smaller exploratory programs managed out of the same office, program expansion and overruns by the demonstration programs can too easily claim funding originally planned for a balanced exploratory development program.

The Ballistic Missile Defense Advanced Technology Center (BMDATC) and Advanced Ballistic Re-Entry Systems (ABRES) technology base programs have suffered the same problem as those of DARPA. Expansion of demonstration programs within a constrained budget has forced major cutback in the longer range technology programs. There are some areas where BMDATC has a strong position, in particular, software and architecture for real-time data processing. Because their funding is 6.3 money, there is no formal mechanism for coordinating these activities with the rest of the DoD technology base programs.

TABLE VI-1

DEMONSTRATION PROJECT AT NOSC AND NWC

BASIC TECHNICAL PROFESSIONAL PAY
LEVELS AND CLASSIFICATION LEVELS



- PERFORMANCE DIRECTLY AFFECTS PAY
- TRAINING AND CORRECTIVE ACTIONS INDENTIFIED
- REVIEWS AT 6-MONTH INTERVALS
- PAY ADJUSTED ANNUALLY

CHAPTER VII

SUMMARY - FINDINGS AND RECOMMENDATIONS

CHAPTER VII

SUMMARY - FINDINGS AND RECOMMENDATIONS

A. TECHNOLOGIES THAT COULD MAKE AN ORDER OF MAGNITUDE DIFFERENCE

1. Relating Scenarios and Technology Priority to Investment Decisions

Findings:

In reviewing the planning processes within the Services, there was no consistently applied linkage between scenarios, technical opportunities, and risks to investment decisions in the technology base. Further, there is no formalized prioritization process for technologies outside of that implicit in the technology base budget. In fact, the work of diverse elements of the Services often incorporates a different set of scenarios. The figure of merit method used herein was derived due to the lack of a uniform structured process within the Services.

Recommendations:

The USDRE allocate resources to the Services and all levels of the technology base on a consistent scenario-oriented basis.

- (U) Recognize organizational excellence by evaluation of the matching of resources and technology priorities with the scenarios.

The ASD(R&T) adapt a prioritization and investment strategy approach based on the figure of merit used in this study.

2. Investment Status - Underinvestment

Findings:

Based on a comparison of the technology evaluation herein with the current DoD investment, a number of "Order of Magnitude" technologies were identified which require more aggressive funding:

- Machine Intelligence
- Advanced Software/Fast Algorithms
- Short Wavelength Lasers
- Hardening of Advanced Electronics
- Microprocessor-Based Personal Learning Aids
- Fault Tolerant/Fail-Soft (Self-Policing) Electronics

Recommendations:

The ASD(R&T) increase funding in these areas (as outlined in Chapter II of this report.)

3. Investment Status - Overinvestment

Findings:

Although no effort was made to recommend specific programs which should be deleted, several categories of activity were highlighted for deemphasis:

- Areas of duplication with NASA (e.g., remote sensing, propulsion)
- Overexpansion of DARPA programs into areas which overlap with other major DoD/Service programs (e.g., forward swept wing, VLSI, fiber optics)
- Nonproductive duplication of the generic technology base by the three Services
- In-house execution of the basic research program (6.1).

Recommendations:

The ASD(R&T) undertake a thorough review of these areas with the goal of eliminating duplication and reducing investments in these areas.

4. Investment Strategy

Findings:

A review of the process by which each of the Services develops its investment strategy was conducted. Although each Service has a structured approach to technology base planning, there appears to be a failure to come to grips consistently with the full range of questions necessary to develop a well founded investment strategy "catechism":

- What is it? What is this effort trying to accomplish (defining the technology sufficiently well to discriminate it from other similar technologies)?
- Why is it important? Assuming success, what difference can it make to the user or in a mission area context (taking into account the nature and limitation of current practice)?
- What is the current status? What is the DoD program? What should it be? What is new about the proposed effort and why will this approach be successful?
- How long will it take? How much will it cost? What are the measures of success?

Recommendations:

The USDR&E should direct the military departments and DARPA to use this investment strategy "catechism" in all future technology base planning and POM guidance.

5. Management of the "Order of Magnitude" Technologies

Findings:

There is a diffusion of the DoD effort in many of "order of magnitude" technologies throughout DARPA and the Services. This diffusion appears to lead to many subcritical efforts without the impact of a more focused approach.

Recommendations:

The ASD (R&T) formulate vertically integrated technology base programs with fenced funding, similar to VHSIC in the following areas:

- Machine Intelligence
- Advanced Software/Algorithm Technology
- High Power Microwave
- Advanced Materials (Rapid Solidification Technology, Advanced Composities)
- Microprocessor-Based Personal Learning Aids

6. Overall Level of Funding of the Technology Base

Findings:

The overall level of funding in the technology base is assessed as being adequate. If properly organized and managed, 2% of the DoD budget (the current level) is probably adequate. This ideal cannot be achieved unless the decision making and allocation process within DoD is restructured to reflect the planning methodology outlined in this report.

Recommendations:

None

B. TECHNOLOGY TRANSITION

1. Barriers to Transition

Findings

The following barriers to the transition of technology into operational systems are highlighted:

- Partitioning the research, development, and production process into separate organizations and contractors
- Lack of involvement of potential users in the establishment of requirements and the resulting programs
- Lack of fenced budgets to allow the product activities to fund transition of desired technology
- The failure to meet an "opportunity window"
- The lack of a risk/reward system
- Existence of a mature hardware options

DoD, as a whole, does not adequately address these barriers. There is very little emphasis on technology demonstrations which accurately portray risk reduction, payoff and cost offset, and later stage production or to conduct "test marketing" experiments. The system has little incentive to exploit or respond to new technological capabilities. The organization and spatial separation of technical and systems people inhibit transition. Discontinuity of funding, indecision and the short term orientation of many key decision authorities heighten this problem. A champion on the user side is often not present.

Recommendations:

In order to better focus DoD resources on the transition issue that the USDRE direct the creation of an advanced projects agency charged as follows:

- To develop subsystem or system experiments to quantify the maturity (risk and cost of FSED) of emerging technology
- To conduct "test marketing" experiments
- To be populated by people in the Services

However, if a new agency is not formed, the DoD should not terminate DARPA activities in this area. The function is too important not to focus OSD attention on it. Also, the Services should fence a large 6.3A budget for conducting the needed demonstrations.

2. Technology insertion

Findings:

The DoD does not plan adequately for successful technology transition throughout the life of a system. Such plans are often injected only as an afterthought.

Recommendations:

The USDRE require technology insertion plans as a basic and fundamental part of program planning.

C. THE UNIVERSITY CONNECTION

Findings:

The universities and DoD need each other. DoD needs the scientists and engineers trained by the universities; it needs the faculty pool of scientists and engineers working in the DoD area as generators of new ideas and results, as expert consultants and as advisors. The university research base for defense preparedness is in considerable disrepair and therefore in need of upgrading in faculty, equipment, facilities and support. It is a problem broader than DoD, but DoD has a specific interest and responsibility.

Mechanisms are needed to stimulate quantity and quality in the training of scientists and engineers in defense-related subjects, especially in advanced technologies, to encourage their employment in the universities and DoD activities.

In the broader terms, the stimulation can be provided by increased support -- government and industry -- of R&D in the universities, by fellowships for graduate training in specialized fields, and by equipment acquisitions that will have an impact on research of high DoD leverage. In addition there are numerous DoD administrative policies and procedures that are detrimental to the ability of the universities to carry out these activities and need mutual discussion and resolution, for example, export controls on information and the DoD procurement process.

Finally, the DoD must respond to the House Armed Services Committee for a study on "University Responsiveness to National Security Requirements." The DoD response will require greater in-depth study than was provided by this DSB Panel.

Recommendations:

Based on these findings, the following recommendations were made:

1. The USDRE direct the services to increase 6.1 basic research performed by universities by 25% in real growth over the next three years.

2. USDRE authorize each of the services to award 100 S&E graduate fellowships annually.

- In areas of DoD interest - similar to those of the DoD laboratories.

- $20K/year to continue until completion of degree but not to exceed 3 years (part to students and part to university)

- Competitive -- awarded by Congressman

- Must work one year in DoD lab for each year of fellowship support granted

3. The USDRE direct the DAR Committee to revise current procurement policies and regulations to allow:

- Additional IR&D -- 0.5% against negotiated base over present ceiling -- for industry support of university R&D

- Treatment of university indirect costs similar to that used by U.S. Dept of Health and Human Services (HHS)

- Simplification of research procurement from universities

4. The USDRE establish with the universities an accommodation and basis for the implementation of current export controls on information relating to munitions list technologies.

5. The ASD(R&T) direct the services to create a DoD thrust via the OSR's to upgrade equipment in universities. This focus should be on equipment that can impact university research of highest DoD leverage (software, design automation, machine intelligence, etc.)

- The upgrading of computer resources is the highest priority based on this algorithm.

- Generally, DoD should support NSF efforts to upgrade equipment in universities.

D. GENERAL FINDINGS AND RECOMMENDATIONS

Findings

As a result of addressing the three previous questions (The "Order of Magnitude" Technologies, Technology Transition, and The University Connection), a number of recurring themes arose with regard to the state of DoD in-house laboratories, DoD S&E personnel, and DARPA.

The following findings draw themes together:

- DoD laboratory prospects for improvement are poor, given their current state and the constraints that afflict them. Of particular concern is the weak, fragmented and duplicative effort in key areas, e.g., computer science, machine intelligence, software, VSLI and signal processing.

- Over the years, there have been a number of studies by various groups of the DoD laboratories...good advice which is rarely heeded.

- There is an impending crisis in personnel and facilities in the DoD laboratories that will seriously degrade the defense posture in a very few years.

  - The average age of civilian S&E is 44 years.

  - Because of the inability to competitively hire highly qualified individuals at lower levels (GS5-7-9), the work force is continuing to age.

  - The primary skills of this aging work force are becoming outdated.

  - Because of attrition and personnel ceilings, the quality of personnel may be eroding.

  - Raising grade levels or increasing pay without other reforms will not solve these problems in the highest leverage areas.

- DARPA

  - The growth in the DARPA technology base program has greatly exceeded the capability of the staff to properly execute the program.

  - There appears to be no comprehensive filtering of DARPA programs versus on-going service efforts. Further DARPA results are not widely disseminated and therefore not sufficiently critiqued.

  - There is no clear, organizational division within DARPA of responsibility for the exploratory development programs (6.2) and large scale technology demonstrations (6.3A). In fact, the budgets for these two classes of R&D are often mixed.

Recommendations:

Based on these findings, the following recommendations were made:

1. To help the hiring and retention of the skills necessary for a viable laboratory structure, USDRE direct that the highly exciting and effective personnel experiment being conducted at NOSC and NWC or its equivalent be implemented for DoD laboratories. The most exciting features of this experiment are:

  - Reduces paperwork
  - Makes performance the foremost criteria for salary increases, retention, promotion, etc.
  - Enhances flexibility and allows faster decisions.

2. USDRE, in conjunction with Service technology base managers, designate lead laboratories in generic technology base areas within each Service. Candidate technology areas include:

- Space systems related technology (components, hardening, etc.)
- Airborne radar technology
- Airborne electronic warfare technology
- Electron devices
- Infrared technology

3. USDRE:

- direct that the Services review DARPA programs over $30M (total program costs -- not annual) from the point of view of potential future military applications, operational needs, and transition plans.
- establish a mechanism to ensure coordination of system technology base programs (such as BMDATC and ABRES) with the rest of the DoD technology base activity to ensure that multiple system requirements are included in the development of the technology base investment strategy.

APPENDIX A

DSB TECHNOLOGY BASE SUMMER STUDY
TERMS OF REFERENCE

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

RESEARCH AND
ENGINEERING

2 JUL 1981

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Summer Study: Technology Base

You are requested to undertake a Summer Study to assess the health of the U.S. national defense technology base, within and outside the government. Estimates of Soviet military research and development show that the Soviets have steadily increased their outlays for military RDT&E over time, and are now spending roughly twice that of the United States. To date, the United States has maintained leadership in most of the basic technologies critical to defense, partly because of a focus on critical technology edge and the momentum in defense technology built up during the 1960s. However, it appears that the United States may be losing the lead in some key technologies.

The United States strategy for dealing with the Soviet military challenge is critically dependent on the effective defense exploitation of the broad based U.S. technology. This study should address the following questions:

1. What technologies are critical to future (1990-2000) defense capability? What are those technologies that would contribute to roughly an order of magnitude improvement in system performance, cost, etc.? How are these technologies identified? Are the Soviets gaining ground? Is the investment on the Technology Base of less than 2% of the total defense budget adequate? If not, what is a reasonable level of expenditure and what should be the management and investment strategy within the technology base?

2. Is the process of transition from technology base to weapon systems adequate? If not, what changes are needed to accelerate the process of transition?

3. Are the universities responsive to national security requirements? If not, what actions should be taken to improve the responsiveness of universities?

4. Is the DoD relationship with the basic research community, creative individuals and small innovative firms adequate? If not, what changes should be made to improve the DoD utilization of these resources?

5. Are the scientific/engineering personnel resources adequate to meet the requirements of the defense technology (commercial or government)? What actions should be taken to eliminate critical personnel shortages?

Items 3, 4, and 5 are to be considered provided sufficient time and resources are available to the Summer Study.

This Summer Study topic is sponsored by Dr. George P. Millburn, Acting Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology). Dr. George H. Heilmeier has agreed to serve as Chairman. The Executive Secretary will be Dr. Samuel A. Musa, OUSDRE/R&AT.

R. D. DeLauer

APPENDIX B

REVIEW OF PAST STUDIES

APPENDIX B

REVIEW OF PAST STUDIES RELATED TO THE DOD LABORATORY/UNIVERSITY ISSUE

1. Make the overall research strategy less vulnerable to changing environmental influences (e.g., Congressional mood swings)

Reports where these recommendations appeared: A., C., E., G., I., K., S.*

2. Improve communication/cooperation between DoD in-house laboratories and the general research community.

Reports where these recommendations appeared: C., D., E., G., H., J., K., M., S.

3. Shift the ratio of intramural to extramural research toward outside contracts and/or increase the percentage of university/small business basic research.

Reports where these recommendations appeared: B., C., F., K., M., T.

4. Increase block funding to basic research programs (both out-/in-house) in order to maximize innovation and permit flexibility.

Reports where these recommendations appeared: B., C., F., G., K., S. T.

5. Establish a review mechanism for university, contractor, and in-house research programs that bases further funding on the quality, productivity, and impact of the research.

Reports where these recommendations appeared: A., C., E., G., H., I., K., M., T.

6. Remove the "albatross" of relevancy from the necks of researchers (both intramural and extramural) in order to free scientists/engineers from the limiting effects of such constraints. Make the criteria of relevancy apply to broadly defined fields and disciplines rather than to an individual program area.

Reports where these recommendations appeared: C., D., G., H., K., M., T.

7. Overcome the "inertia to change" evident in some DoD in-house laboratories (which inhibits progress towards more advanced technologies) by simplifying the complicated, layered management structure.

Reports where these recommendations appeared: A., B., C., F., G., H., I. K., S., T.

*See key on second page for report references.

8. Enhance the quality of the research in in-house laboratories by improving the position of in-house scientific personnel:

- Make salary/benefits competitive with industry
- Make career options more promising/stable
- Do not subject quality technical personnel to the vagaries of budget management nor to the public disclaim accorded all civil service workers.

Reports where these recommendations appeared: A., C., E., H., I., J., L., T.

9. Avoid the trend toward over-burdened, overly comprehensive (full spectrum) in-house laboratories. Consolidate and focus the research and eliminate diversification at the laboratories and/or FCRC's.

Reports where these recommendations appeared: A., B., D., F., G., H., T.

10. Increase the amount and timeliness of DoD implementation of high quality, front-line, capital equipment at facilities (both out-/in-house).

Reports where these recommendations appeared: C., H., K., L.

KEY (The corresponding background summaries follow in the remainder of the appendix.)

A. Report of the Ad Hoc Committee on In-House Laboratories, Army Scientific Advisory Panel (ASAP), December 1963. (page B-4)

B. Management of Federal Contract Research Center, DDR&E, June 1976. (page B-6)

C. Proceedings of an AAAS Symposium on "How Much Does the Defense Department Advance Science?" January 1980. (page B-7)

D. Required In-House Capabilities for DoD Research, Development, Test, and Evaluation, OUSDRE, October 1980. (page B-9)

E. Ad Hoc Group on Scientific Personnel, ASAP, April 1964. (page B-11)

F. Report of the DSB Task Force on Technology Base Strategy, October 1976. (page B-13)

G. Report of the Panel on Research and Exploratory Development, DSB-NBS, July 1967. (page B-16)

H. Report of the Science Advisor's Panel on Basic Research in the Department of Defense, OSTP, June 1978. (page B-18)

I. Historical Perspectives in Long-Range Planning in the Navy, NRAC Study, September 1980. (page B-19)

REPORT ON THE AD HOC COMMITTEE ON IN-HOUSE LABORATORIES

ARMY SCIENTIFIC ADVISORY PANEL DECEMBER 1963

Goals

(1) To strengthen the Army in-house research and exploratory development activities by analyzing funding to the Army laboratories. How can Army labs be provided with the resources necessary to carry-out sound, long range research programs?

(2) To identify and analyze problems related to funding, including organization, research, objectives, personnel, and facilities.

Methodology

The study utilized interviews and/or questionnaires to obtain first-hand data from Army in-house personnel. They also gathered fiscal data, mission statements, and utilized other studies as supporting documentation.

Results

The panel results fall into two major areas:

(1) Those relating to planning, organizing, and controlling the effort.

(2) Those relating to proper allocation of funds to ensure maximum efficiency and produce R&D results that warrant annual investment.

Recommendations

(1) Reassess the long-term research-exploratory development objectives (and plans) in order to identify broad areas of technical interest to future Army mission needs.

(2) Redefine and clarify the Army mission, especially that of its laboratories, in light of other Service missions and RDT&E.

(3) Reorganize and toughen Army RDT&E management to prevent division of 6.1/6.2 funds or reprogramming of funds within 6.1/6.2 away from important areas.

(4) Make 6.1/6.2 budget arguments less vulnerable to changes in funding methods and congressional mood swings. Protect research freedom.

(5) Stress the importance of consolidation of those labs producing state-of-the-art, front-line research.

(6) Ensure that Army RDT and management and ASA(R&D) are involved where any budget, diversion, or reprogramming of funds (greater than twenty percent) is suggested for the 6.1/6.2 budgets.

(7) There is an overall awareness of the need to protect the freedom and quality of research and exploratory development. This awareness extends to the recognition that only by stringent, forceful management and documentation of R&D activities can a vital technological base be maintained.

(8) Secondary recommendations deal with personnel management, maintenance of facilities and practical organization. The recommendations include steps to improve the morale of in-house lab personnel and to increase the efficiency of maintaining the lab facilities.

MANAGEMENT OF THE FEDERAL CONTRACT RESEARCH CENTERS (FCRC)

DDR&E JUNE 1976

A management report based on a DSB Task Force Study on FCRC utilization (February 1976). This task force surveyed previous studies on FCRC's and interfaced with the FCRC communities in order to review FCRC policy.

Goals

1) Evaluate the existing FCRC's in light of how and why DoD uses them. Consider specifically whether the special relationship of the FCRC's to DoD continues to provide the quality, specialized services for which they were engendered.

2) Review the present fiscal ceiling concept for managing the FCRC's in light of the contention that such ceilings lead to technical stagnation and low personnel morale.

3) Suggest alternative management strategies for the FCRC's, particularly the Study and Analysis and System Engineering/Technical Direction FCRC's.

Recommendations

The FCRC's should be retained because their unique relationship with DoD enables high quality, technically intensive, and efficient services to the DoD Mission. DDR&E (and DSB) recommended the following specific actions to enhance FCRC management performance:

1) Discontinue FCRC status for some facilities (e.g., APL (Johns Hopkins), Anser, ARL (Penn State)).

2) Continue some FCRC's with manpower or ceiling controls (e.g., CNA, IDA, MIT Lincoln Lab)

3) Make MITRE (Bedford) the DoD C^3 FCRC; eliminate diversification. MITRE (Washington) becomes a non-FCRC corporation.

4) Aerospace continues as AF Space Systems FCRC; eliminate diversification.

5) Split Project RAND from RAND corporation. Redesignate Project RAND as Project Air Force. The remainder of RAND becomes a non-FCRC corporation.

PROCEEDINGS OF AN AAAS SYMPOSIUM

"HOW MUCH DOES THE DEFENSE DEPARTMENT ADVANCE SCIENCE?"

8 JANUARY 1980

Goals

1) Review DoD's overall contribution to the advancement of science in light of its programs designed to foster basic research. Include a historical perspective.

2) Consider the recent allegations that DoD gives too much support to those research programs which are oriented towards solutions to applied problems.

3) Has DoD funding enhanced, or unduly influenced academic research?

4) Assess the impact of the Mansfield Amendment (relevancy) on DoD's ability to fund basic research.

5) Does military secrecy affect academic science?

6) Determine the reasons underlying DoD's drop from first to fifth place in agency support of basic research and review the effect this drop has on the advancement of science and protection of national security.

7) Review future possibilities for DoD support of basic research

Methodology

The form for this review was a week long symposium at the AAAS annual meeting. Five speakers, with varied relationships to DoD-supported research, gave lectures on the following subjects;

- The National Value of DoD-Sponsored Research
  George Gamota (Department of Defense)

- DoD In-House Basic Research
  Alan Berman (Naval Research Laboratory)

- History of DoD's Support of Science
  Edward Salkovitz (ONR)

- A Broad View of DoD and Science
  Edward Teller (University of California, Lawrence Livermore Laboratory)

- Science Sponsorship by the Department of Defense
  George Wald (Harvard University)

A discussion was held after the lectures were completed.

Results

1) DoD has revised an imbalance in the funding fraction of support to university research by emphasizing and increasing the allotment to academic institutions in a generally enhanced research budget. Over the last three years the overall basic research budget has increased by 30 percent; university support has increased by nearly 70 percent.

2) In the same three year frame, DoD has substantially increased its support of block or cluster programs at universities. This action is oriented toward maximizing innovation and flexibility; qualifications for award of such support include good management, active pursuit of the university/government synergism, and a leadership base.

3) DoD is increasing the capital equipment expenditures for its researchers. The goal would enable the use of at least ten percent of contractual funding for equipment purchases.

4) In order to improve DoD communication with the research community, a series of 12 bi-monthly research topical reviews was implemented in the fall of 1979, devoted to a specific discipline and open to the public.

5) DoD has established a department-wide, uniform, one-page research contract to reduce paperwork and red tape.

6) The dedicated, competent, and superior quality scientists and engineers in DoD in-house laboratories should not be subjected to the public disclaim accorded to all who work for the U.S. government. Their professional position should not be cut without relation to the mission of laboratories; grades should not be arbitrarily frozen; and the number of senior positions should not be rigidly limited.

7) Mission of DoD in-house laboratories.

- To provide dedicated technical staff who give continuity and corporate memory to the system's acquisition process.
- To provide competent and knowledgeable technical assistance in the design, development, and procurement of new military systems -- in short, to make the military services smart buyers.
- To provide advice and consultation during the introduction of new military systems into service use.
- To be responsive to the opportunities to improve military system capability through new scientific discoveries and by new developments of technology.
- To maintain a research base in those areas of science and technology which are only of interest to DoD.
- To couple with and contribute to the general science and technology effort to the nation.

OUSDRE REQUIRED IN-HOUSE CAPABILITIES FOR DEPARTMENT OF DEFENSE RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

1 OCTOBER 1980

Goal

To describe the capabilities of the Defense Department's RDT&E programs at in-house facilities in light of the fundamental responsibility of the department.

Results

Capabilities of DoD In-House Facilities

I. Major Functions

1. Basic scientific research
2. Applied research (exploratory development)
3. Advanced development
4. Assessment of science and technology base
5. Mission analysis
6. Concept exploration and system demonstration/validation
7. Full-scale engineering development
8. Engineering support of production
9. Test and evaluation
10. Major RDT and facilities
11. User services and support of operating forces, including product improvement

II. Supporting Responsibilities

1. Making DoD a "smart buyer" in support of decision making in a technically sophisticated marketplace
2. RDT&E program/project management
3. Technical intelligence assessment
4. Providing options for future systems
5. Providing RDT&E in areas of limited industrial or academic interest (technical expertise for military planning process; defuse contractor access to pertinent Data)

6. Exploitation of new technological opportunities

7. Understanding of and interaction with the military user

8. Independent research and development program evaluation

9. Contractor proposal and performance evaluation

10. Providing quick reaction to operational problems

11. Interfacing with scientific and engineering community

12. Cooperative R&D with allies

13. Integrating logistics support

14. Reliability and maintainability

15. Mobilization requirement

16. Producibility

17. Design-to-cost management

18. Human engineering and manpower considerations in system design and operation

19. Operational system safety

20. Examples of special areas of technology:

    a. medical R&D
    b. manufacturing technology
    c. environmental assessment

AD HOC GROUP ON SCIENTIFIC PERSONNEL
ARMY SCIENTIFIC ADVISORY PANEL
APRIL 1964

Goals

The panel was tasked to assess the Army's effort to maintain and improve the effectiveness of scientific personnel in Army laboratories. Two questions formed the basis of the inquiry:

a) Is the Army taking full advantage of available/feasible means to improve the effectiveness of its scientific personnel?

b) What should be done to enhance the prestige of scientific personnel in Army laboratories?

Recommendations

A. To attract scientists of quality:

1) The Army must (with other services) increase the initial salaries offered to entry levels BS, MS, PhD scientists to match industry's offers - especially in the physics/engineering field.

2) Step-up summer help/work-study programs: allot more spaces; exempt them from manpower authority.

3) Adopt the Skifter committee (see ASAP, Nov. 63) #11 recommendation which modifies personnel procedures to keep staff at optimum levels and attract quality personnel.

4) Use ASAP to recruit senior staff.

B. To increase effective utilization of Army scientists in R&D programs (especially to upgrade competence, assist professional development, and enhance prestige).

1) Management position applicants should have a proven, solid research competence as well as a good management record.

2) Make manpower authority more flexible; enhance career mobility.

3) Increase communication between Army scientists, the Army, and the general scientific community.

4) Improve relationship between civilian/army scientific personnel (see ASAP Skifter report, Nov. 63).

5) Make the career program for military officers more attractive so as to enhance the civilian-military R&D team.

6) Find means to increase incentives to senior R&D staff.

7) Headquarters Army R&D Staff should establish a scientific personnel element to review, monitor, and recommend actions to strengthen the Army's scientific personnel programs.

C. Assess effectiveness of the effort to increase quality of scientists recruited/retained by Army R&D organization:

1) Keep data on all aspects of scientific personnel policies. Develop methods to judge trends in quality of technical personnel.

2) The ASAP should review this problem in 18 months to 2 years.

REPORT OF THE DSB TASK FORCE ON TECHNOLOGY BASE STRATEGY

(OCTOBER 1976)

Goal

Provide DDR&E with an independent assessment on how well funding resources were allocated among the many technical areas of the base.

Consider, specifically, those areas where an increase or decrease of current allocations seem appropriate, and where opportunities for focus or integration of effort appear to offer better returns.

3 Panels were formed:

- Environmental Life Science
- Electronics
- Engineering Technology

Strengths in the general Technology Base:

- Technology Base is recognized an an important defense activity by DoD management.
- Technology Base efforts continue to pay off (especially yearly incremental advances over 10-20 year periods).
- There is a presence of a quick-action, high risk, high payoff technology operation (DARPA's role).
- Reasonable allocation level for the broad scientific/technology areas comprising the base.

Problem areas with Technology Base (all of which have been noted in previous reviews):

- DoD in-house laboratories are hampered in the quality of their contribution to the Technology Base by a complicated, layered management structure.
- The Technology Base is subject to an "inertia to change," stemming in part from the management structure. Over time this trend:
  - protects investment in low priority endeavor.
  - does not encourage orderly shifts to new, higher potential/payoff areas.
- Fields of endeavor are fragmented between many different organizational units.

- Technology Base tends to be isolated from system developer and is not sensitive to operational needs.

Some work has been done on these long-standing problem areas:

- Selective use of block funding to laboratory technical management for Technology Base work

- Increased contract to in-house ratio for Technology Base work

- Army's plans to set-up integrated Development Centers to include laboratory Technology Base work

- Studies (e.g., Navy "Strike-Warfare Exercise," AF "Technology Base Investment Strategy Exercise") are better assessments of impact and cost-effectiveness of investment in specific Technology Base areas.

Opportunities for Funding Increases:

- Training R&D (e.g., use of simulators)
- Software Cost Reduction
- Gas Turbine Development
- Environmental Factors Affecting Weapons System Performance
- C^3 for Tactical Field Commanders
- Digital Controls for Power Plants
- Peacetime Environmental Quality
- Adaptive Acoustic Arrays
- Substitutes for Critical Materials

Opportunities for Funding Decreases:

- Surface Effect Ships
- RF Electronic Systems
- Special Computers and LSI
- Personnel Classification, Selection, and Assignment
- Advanced Fighter Technology Integration

Opportunities for Integration and Focus

- RF Electronic System
- Fuzing
- Combat Casuality Care Systems
- Material and Devices for Electronic Systems
- Gun Technology

F

The Task Force concludes that while actual Technology Base funding is implemented through budget element allotment, DoD should continue to use the independent perspective offered in the Technology Coordinating Papers in order to ensure against duplicated effort or oversights of important areas.

The directed trend towards larger contract to in-house ratios implies a revitalization of industrial and university-based defense research. It also implies a healthy trend for the nation and is contributory to an innovative and creative Technology Base.

Prioritization of Technology Base effort performs reasonably overall. Senior levels must be alert to trends toward misplaced investment because of the narrowly-focused, hardware-based budget process. All types of Technology Base investment must be explored (and has been to a certain extent in the Air Force and DARPA).

REPORT OF PANEL ON RESEARCH AND EXPLORATORY DEVELOPMENT

DSB-NAS (JULY 1967)

Goals

Assess, both qualitatively and quantitatively, the impact of increased budget reductions on the 6.1 research and 6.2 exploratory development programs. Issues include:

(1) "Selling" the long-range benefits that 6.1/6.2 programs have on a strong, mission-supporting technology base in terms of traditional cost-effectiveness.

(2) Clarifying the vital relationship between education and research, in light of funding cutbacks to universities. (Understand why cutbacks were suggested.)

(3) Indicating, as concretely as possible, the impact of budget restrictions on in-house labs, the defense industrial R&D base, and small business.

(4) Developing methods to determine the optimum funding level of 6.1/6.2 and to allocate resources to various fields.

(5) Exploring ways to influence and estimate future Congressional moods.

Methodology

The DSB addressed the task issues through analysis organized into the following groups:

(1) Impact of Budget Funds

(2) Approaches to Determination of 6.1 and 6.2 Funding Levels

a) Comparison with Industry
b) Comparison with Potential Adversaries
c) Health of Fields Underlying Defense
d) Production of Technically Trained People

(3) Working with Congress

Results

(1) Expand the managerial support and staff allocated to the planning and interpretation of 6.1 and 6.2 programs in order to:

- Move trend away from system orientation back towards discipline orientation.

- Prepare a quantitative analysis of RDT&E expenditures in DoD and industry -- give credible basis of comparison for R&D funding.

- Improve quantitative rationale for funding 6.1 and 6.2.

(2) Develop better interaction with services and technical community to rank order promising disciplines for DoD support.

(3) Strengthen position of "OXR" (advanced research) program managers.

(4) Develop "core contracts" to strengthen research in fields of DoD interest as a way to "harvest" the output of universities, researchers, and consultants.

(5) Give more stress to long-range relevance in 6.1 funding.

(6) Establish a planning committee to review/improve the performance of FCRC's.

(7) Support consolidation and efficiency improvement for service in-house laboratories.

(8) Impress upon Congress the value of long-term payoffs from research through tighter rationales, aggressive and technically oriented arguments, and greater interaction with Congressional supporters.

(9) Emphasize and argue the importance of university research (and funding) to high quality graduate and/or undergraduate study.

REPORT OF THE SCIENCE ADVISOR'S PANEL ON BASIC RESEARCH IN THE DEPARTMENT OF DEFENSE
OSTP - 22 JUNE 1978

This report was given to an OSTP Steering Committee on Basic Research in Mission Agencies.

<u>Goals</u>

1. Review the policies and practices of the basic research program in the Department of Defense.

2. Assess the recent DoD policy and methods to reverse the decline of DoD-supported fundamental research and to increase the DoD basic research budget in constant dollars.

3. Examine the institutional nature of the DoD basic research program.

<u>Recommendations</u>

1. DoD must support an extensive, vigorous, and high-quality basic research effort.

2. Affirm the critical importance of basic research to DoD and clarify the policy for support of such research at the Secretarial level.

3. DoD must continue its substantial increases in the level of basic research funding, but <u>must</u> ensure that the implementation achieves the intended objectives of such increases.

4. Apply the criteria of relevance primarily to broadly-defined fields and subfields of science rather than individual programs.

5. Utilize basic research facilities (universities, in-house labs, industry, and non-profit organizations) in a manner which maximizes quality and acknowledges the distinct contribution each can make.

6. Explore the channels through which communication between DoD and the basic research community can be effectively increased.

7. Improve the DoD management of basic research through:

   - Appointing of an official to provide full-time, broad oversight for basic research.

   - Increasing awareness of the existence of gaps in basic knowledge of certain fields within DoD research programs. Actions should be taken to connect such deficiencies (e.g., in software, in human factors).

   - Ensuring that when DARPA supports basic research, it employs arrangements which provide the stability needed for productive programs.

   - Making DoD management and business practices in this area compatible with those of the basic research community.

NRAC STUDY: HISTORICAL PERSPECTIVES IN LONG-RANGE PLANNING IN THE NAVY

(SEPTEMBER 1980)

Goals

1) Review some of the Navy's past studies of future seapower needs, particularly ones that served as bases for public justification of major programs.

2) Determine how well these studies were able to account for factors which became important one to three decades thereafter.

3) If important factors were slighted, suggest reasons why those oversights occured.

4) Allow current planning efforts to be informed by knowledge of the past.

Results

1) From 1945, there has been no truly systematic process for doing long-range planning in the Navy.

2) Reasons for the above conclusion include:

   a. Methods for systematic long range planning were not developed nor used by industry until 1950's and 1960's. The Navy adopts business methods more slowly and in its own way.

   b. The Navy did not urgently need long-range planning in the period from 1945 to the mid 1960's. By the 1960's (and Viet Nam) short- and mid-range shipbuilding was more important than long-range planning.

   c. Historically the Navy's internal structure, the nature of naval warfare, will not permit the organizational structure necessary for systematic long-range planning (Naval Officers first, specialists second).

   d. The larger political environment in which the Navy has operated since WWII has severely inhibited active performance/implementation of the necessary long-range planning. The question that requires further investigation is, given changing defense organization, could the Navy have better adopted, and thus better undertaken, crucial long-range planning?

   e. Without adequate access to the documentation of individual policy makers; the influence of such key individuals on Navy long-range planning, and the long-range planning process as a whole, cannot be complete.

3) Observations of the long-range planning process as practiced by the Navy in the studied period include:

   a. A centralized long-range planning office is useful to the Navy (even though it may not accomplish systematic long-range planning) because it allows the Navy to focus and coordinate efforts toward projecting its long term needs.

   b. Such a planning organization is most successful when there is a personal commitment to long-range planning on the part of the CNO and/or the Secretary of the Navy.

   c. That commitment, cannot, however, allow the LRP group to be so tightly controlled as to identify its process with a single policy maker.

   d. A Long-Range Planning organization must be highly placed enough within the Navy to permit its independent operation despite the demands for ongoing operational and short-term planning.

   e. Although oriented toward long-term needs, LRP organization cannot be isolated from current Navy problems. (Note OP-93's review of current policy developments in the 1950's in light of their possible impact on long-term Navy objectives).

   f. The Long Range Planning group must be considered important enough by high policy makers so its studies will impact on Navy policy and operations. To achieve this prestige, the LRP Office must ensure that policy makers are:

      - sensitive to the uncertainties of attempts to predict the future;

      - aware that efforts to quantify planning studies undermines their efficacy and morale; and

      - cognizant that the good work of broadly experienced, high caliber, and well-timed planning personnel must be acknowledged and rewarded.

4) Although the study covered LRP work to 1979, the committee reviewed work done in 1980 and found that although the utility of Admiral Hayward's Long-Range Planning group remains to be seen, it has again accorded such planning its proper place in Navy operations.

ARMY SCIENCE BOARD 1979 SUMMER STUDY
"TECHNOLOGY PLANNING FOR FUTURE FIELDED SYSTEMS"
20 JULY 1980

Goal

Assess Army Technological Status and Plans for future fielded systems in order to attain:

(A) Technological Equivalence to Soviet Fielded Systems by 1985.
(B) Technological Superiority to Soviet Fielded Systems by 1990.

Recommendations

For (A) above:

1. Fully fund major systems now in engineering development, and in procurement. Otherwise equivalence will not be achieved by 1985.

2. Insist on more cooperation among developers, testers, trainers, users and DA to field systems quickly, smoothly, and at a high level of maturity and performance.

3. Improve system performance with Block II Product Improvement Programs (PIP's) by inserting newer technology at appropriate times. Include PIP's in initial production.

For (B) above:

1. Develop and maintain a stable, long-range plan for functional needs which:

   a) projects goals, doctrines, environment, operational concepts, organization, and system needs as well as budgetary constraints.

   b) addresses timing of specific programs; compares RDT&E requirements/procurement funds against availability of funds.

2. Use ad hoc committees to review goals and mature the development of advanced systems concepts and superior technology.

3. Retain competent technical teams to provide competitive work and utilize the unique capabilities of private and government labs.

4. Mandate even more cooperation among all actors in the process for superiority goals than for equivalence goals.

5. Shorten the time to field a system. Identify the adverse actions of others to those who can correct them.

6. Mature systems in the field for 1990 projected systems as well as Block II and Block III PIP programs.

DSB SUMMER STUDY GROUP
FUNDAMENTAL RESEARCH IN UNIVERSITIES
OCTOBER 1976

Goals

(1) Explore ways to rekindle and stimulate the interests of the university science community in problems of national defense.

(2) Determine the obstacles to mutually beneficial DoD-University relationships and develop ways to:

- Improve the quality and long-range character of DoD-University relationships.
- Assure the competence of DoD-supported researchers, especially younger investigators.
- Make DoD support more attractive to university researchers and their institutions.
- Address the problem of "relevance," particularly the Mansfield syndrome, in order to minimize its interference with DoD-University relationships.
- Implement recommended changes or new initiatives rapidly and maximize their credible visibility.

Reasons for Regenerating the DoD-University Relationship

(1) The strength of U.S. fundamental research resides predominantly in universities. DoD must re-engage this strength to ensure a fundamental, long-range component in DoD research to balance the trend toward shorter-range, applied science.

(2) The DoD research strategy should include support for disciplines and study that does not seem immediately relevant to the DoD mission, such as;

a. Fields in which DoD must have a "window" on scientific progress.

b. Fields of interest primarily because of the superlative competence of individuals involved.

Recommendations

DDR&E should take advantage of the favorable climate for fundamental research and seek to secure phased "new funding" up to an annual program level of $100,000,000 during coming budget cycles.

In answer to the problem of relevancy DoD must:

- (Continue to) emphasize the importance and relevance of supporting fundamental research.
- Not demand that a scientist demonstrate the relevance of his research project or program.
- Raise the issue of relevance from individual program levels to the relevance of a field or discipline.
- Demonstrate (at the level of field or discipline) to Congress, OMB, and the public, the relevance of fundamental research to the DoD mission.

Policies concerning fields and disciplines must be developed with consideration of the involved scientific community, coordination with the services and other government agencies, and judgments made on the basis of quality.

The policy for review and selection of proposals for research should utilize some form of peer review mechanism, be developed by or for the Service OXR's, and that mechanism should be explained to academic scientists.

Suggested mechanisims for management and faculty include:

- new funds might be administered directly from within DDR&E.
- new money could be allocated to OXR's or another DoD agency with uniform, specific, and enforceable guidelines.

Ways to improve the attractiveness/visibility of new programs:

- Award large departmental or multi departmental contracts.
- Fund the research of a selected number of academic scientists for five years with a distinctive title such as "Awards for Fundamental Science."
- Implement some form of "institutional general research grant" (similar to NIH General Support Research Programs).
- Modify present arrangements for DoD payment of overhead of grants and contracts so as not to penalize the researcher.
- Give high priority to new equipment and instrumentation with a realistic "total cost" approach.
- Push for a rapid instrumentation of the declared policy to establish the ratio of intramural to extramural research at 30:70.

NRAC STUDY: MAN-MACHINE TECHNOLOGY IN THE NAVY

(DEC. 1980)

Given present trends, the Navy will find itself unable to operate and maintain its systems, in either the short or long term, with the numbers of skilled personnel necessary for effective mission.

The set of circumstances that have created this condition include:

- Increases in external threats
- Expanded mission responsibilities
- Rapid advances in technology
- Rising costs
- Declining availability of human resources
- Changes in societal attitude and values
- Non-competitive military pay and benefits

Goal

To develop methods whereby the Navy can correct the mismatched condition of its personnel and its advanced sensors, weapons, and command-control systems.

Recommendations

(1) Enforce the development and application of man-machine technology in:

- Designing and acquiring new systems (early in the acquisition phase)
- Retrofitting current operational systems

(2) Establish an organization to lead the development/incorporation of man-machine technology into the design of jobs, equipment, and systems for the surface Navy.

(3) Increase the use of standard equipments, modules, and configurations in the Navy.

(4) Reduce complexity of operator and maintainer tasks.

(5) Develop and apply performance criteria and methods for predicting and measuring task complexity.

(6) Close the gap between approval authority for software changes, the fleet authority for software changes, and the fleet elements conceived in order to expedite changes.

(7) Consider increased use of distributed computer technology, standard hardware modules and modular software.

(8) Develop a program to improve productivity aboard ships by application of labor-saving methods and automation of selected functions such as:

- facilities maintenance
- ship administration
- materials handling
- systems operations
- consistency of Condition I & III watchstanding requirements

(9) Information on the mental and physical attributes of Naval personnel must flow to system designers so that enhanced man-machine interfaces and system training requirements can develop.

(10) Provide increased capabilities for fleet units to conduct effective post-school training (individual and tactical team). Adjust training strategies and pipelines to accommodate these capabilities.

DOD SMALL BUSINESS ADVANCED TECHNOLOGY PROGRAM (DESAT)

(1981-82)

Goal

Outlines the DoD program to encourage small business firms which have strong research and development capabilities and experience in high technology science and engineering.

The program seeks to promote innovative solutions to important scientific and technical questions facing the defense community by utilizing the resources of small science and technology-based firms in DoD R&D.

The program is designed to augment existing acquisition processes and to inform DoD research officers more effectively of the technological potential of the small business community.

Results

The program is organized into three phases, Feasibility Research and Development, Principal Research and Development, and Follow-on Development or Production. Awards are consecutive in nature with a firm's receipt of Phase II or Phase III contracts contingent on the performance and promise of the Phase I effort. The content of proposals for all Phases can be found in Sections IV, V, an VI of the document.

In Section III, each Military department and DARPA describes areas which include specific scientific or technological problems in need of innovative approaches toward solutions. The outline of these descriptions follows:

Department of the Army

1. Chemical Defense

    a. Real-time chemical agent detector

    b. Use of advanced sensor for detection

    c. New materials for protective clothing

    d. Decontaminants and contaminants facilities capable of neutralizing a range of chemical agents

2. Combat Equipment and Materials

    a. Technologies that will allow Army equipment to operate on a variety of fuels as they become available.

b. More efficient utilization of fuel in light trucks and off-road vehicles

c. Portable electrical generating equipment, fuel cells, and batteries for field use

d. "Lightweight" materials with improved armor capability

e. Critical material substitutes (e.g., chrome free stainless steels, improved powder sintering)

f. Rugged radiation detector for field use

g. Remote minefield detection system

h. Rapid means for water quality analysis

3. Medical Support

a. Prevention and treatment of militarily important diseases (e.g., dysentary)

b. Rapid assessment of risk of disease to treated casualties

c. The care and management of mass combat casualties

d. Technological aids for research on maxillofacial injury, and dental diseases

e. The medical aspects of chemical defense

4. Human Factors

a. New computer-aided measurement techniques for quantifying performance of military units

b. Novel techniques for prediction of personnel which utilize both verbal and non-verbal means

5. Communications

a. Improved noise suppressant equipment designed to eliminate certain background noises and at the same time permit effective communication

b. Techniques for effective communication in an action electronic warfare situation

Department of Navy

1. Target Detection and Localization

   a. Superconducting quantum interference devices (SQUID)

   b. Special purpose acoustic transducers and sensors

   c. Electromagnetics and broadband antennas (ID: 1 Frequency coverage) (especially low cost, wide band-width)

   d. Theoretical and experimental tools with which to detect and classify nuclear surface/air bursts at sea (e.g., portable shipboard/aircraft systems for tactical deployment)

2. Ocean Physics and Engineering Research

   a. New oceanographic instrumentation

   b. Ocean science research

   c. Remote sensing techniques

   d. Ocean volume reverberation modeling

   e. Acoustic response of the ocean bottom

3. Computers and Software Engineering

   a. Inexpensive photolithography techniques for microcircuit fabrications

   b. Portable, inexpensive (less than $3k) microprocessor, with graphic capability

   c. Modulation and Demodulation (MODEM) hardware and software

4. Human Factors and Personnel

   a. Personnel microwave sensor devices similar to radiation detection badges

   b. Microelectrode sensors

   c. Productivity measurement techniques

   d. Personalized interactive display and analysis system

5. Materials

   a. Physics of semiconductor crystal growth and processing

   b. Physics of multi-layer/macroperiodic solid state structures

   c. Optical quality blue-green laser crystals

   d. Removal of coatings and preparing surfaces for recording

   e. Non-destructive evaluation of materials and structures

   f. Bearing/lubricant performance

<u>Department of the Air Force</u>

1. Fuel Efficient Aircraft Design

   a. Friction and form drag reduction

   b. Aerodynamics of large excursion

   c. High frequency active controls

2. Low Speed Take-Off and Landing

   a. Fluid mechanics of thrust augmented lift

   b. Propulsion systems

3. Manufacturing Processes

   a. Optical recognition

   b. Computer vision

   c. Robotic controls

   d. Optical metrology

   e. Non-destructive evaluation

4. Weapons Systems Automation

   a. Interacting intelligent systems

   b. Stochastic processes in artificial intelligence

   c. Control system dynamics and pattern recognition

5. Defense Against Chemical Agents

   a. Detection and Analysis

   b. Chemical Characterization

   c. Interfacial phenomena

   d. Pharmocology/toxicology

DARPA

1. Advanced Solar/Electro-Chemical Power Sources

   a. High temperature cell matrix material

   b. Catalyst

2. Advanced Optical Coatings and Long-Life Switches

3. Innovative Controls and Displays for Military Flight Vehicles

4. Solid Lubrication Concepts in Element Bearings

5. Electro-Optical, Radar, and Electromagnetic Signal Intercept Fields

LOOK FORWARD 20 YEARS, VOLUME I

(AFSC) MARCH 1980

Goal

A look into the future with a goal of predicting the technologies of the 21st century.

In an attempt to look at technologies rather than systems of the future, the panels were divided into the following groups:

- Basic Science
- Aeronautical Systems
- Communications -- ECM-ECCM Computers
- Weapons
- Space
- Operations and Support

Results and Recommendations

A. Space Based Surveillance Thrusts:

1. Large Aperture Surveillance
2. Spacecraft Energy Systems
3. Spacecraft Environment Interaction Technology
4. Laser Hardened Optics
5. Monolithic IR Sensitive Focal Plane Arrays
6. Integrated Passive Damping

B. Military Man in Space Thrusts:

1. Manned Military Space Vehicle Technology
2. Predictive Toxological Testing
3. Optimum Man-Machine Decision Making Architecture for Space Systems
4. Simulation of Integrated Technologies for Space Systems

C. Recommendations to Improve Space System Technology Management:

- Establish a Joint Director of Science and Technology/SP/CC review of 6.3/6.4 programs.
- Create an on-site civilian/military contingent at headquarters SD as a DC detachment.
- Form an ad hoc group to perform semi-annual, in-depth roadmapping of 6.3/6.4 prior to POM/BES sub-mission decision points.

D. Other Specific Recommendations:

Point Defense

As an absolute minimum the Air Staff/AFSC should establish a focal point for planning for the defense of our air bases. This planning should encompass the necessary technology base and system programs to guarantee survival of air bases in intense environments such as Europe.

Chemical Warfare

Establish an Air Force technology base program in Chemical Warfare to investigate and develop defensive and offensive concepts and capabilities unique to the requirements of the Air Force. A realistic start within 6.2 program funds would be more responsive to needs and direction than massive defensive/offensive CW programs.

Logistics

Establish an AF management activity, provide dedicated resources, and appoint appropriate authorities to be responsible for the conduct of logistics research, development, and application (O&E arena).

The logistics research activity should be a joint AFSC/AFCC office with joint manning from both commands (for model - see PRAMPO).

Fully exploit using command representatives, and knowledge gained by FTD activities.

AFHRC should have a full-time place in the activity to conduct manpower effectiveness analysis and to interface with supporting AFHRC activities.

Determine, through detailed analysis, the most effective organizational structure to accomplish logistics research.

Personnel Productivity

To improve wartime productivity and peacetime efficiency of personnel:

- Establish HRC programs to investigate:
  - The personnel factors in a combat effective work force
  - Combat surrogate training for increased readiness
  - Combat effective maintenance organizations
  - Weapon system design for personnel productivity
- Establish an organization in human resources to:
  - Identify research requirements
  - Plan new systems
  - Implement new technology

ASAP AD HOC REVIEW OF THE 1974 ARMY SUMMER STUDY REVIEW

(OCTOBER 1975)

Goal

To review the actions resulting from the Army's 1974 Summer Study which addressed two major areas: Mission Area Deficiencies and Opportunities, and Ballistic Missile Defense.

Specifically:

- Review the 1974 Summer Study Findings and Recommendations and determine the status of their current validity and implementation by the Army.

- If needed, make further recommendations. Make recommendations regarding possible study areas for the 1976 Summer Study.

Recommendations

The committee reviewed each sub area of the two major assessment divisions and subsequently reaffirmed most of the recommendations made by the 1974 group both in terms of their interpretation and implementation.

The use of a system that would allow all elements of the Army to operate in a common electronic grid with the Air Force and Marines and the importance of valid identification warrants more concern and action in TRADOC.

Re-emphasize the importance of EW training and use.

The following firepower areas are suggested for further analysis:

1) Light Airlifted Division
2) Combat in Urban Areas
3) Fire Effectiveness Assessment (Real-time tactical)
4) Tac-Fire Revisited
5) Keep requirements consistent in order to cut R&D spans; get weapons out of R&D earlier ("lessons-learned")

Re-evaluate overall concept of terminally guided weapons rather than just the hardware problems.

Consider the use of lightweight vehicles to carry lightweight weapons.

Operational concept tasks need a much stricter analytical back-up before the tests are designed.

Assess field computers in light of their place in total tactical firepower as well as hardware development

Develop a clear, concise production policy to decide which 20 mm and 40 mm programs to pursue.

Discover why the recommendations of the Mobility Enhancement and Denial subgroup have not been acted upon; perhaps whith an eye towards better definition (by TACOM) of its R&D activities.

The recommendations for mine detection and neutralization were very sound, and were particularly ingenious for the related area of barriers.

Renew efforts to establish a centralized responsibility for camouflage, and ballistic, CW, and EW environment threat survivability, especially the development of potential conflict scenarios and vigorous test and evaluation.

No response was given to the following ASAP recommendations on Field Army Air Defense:

- A call for an air defense plan, not an air defense missile plan
- The issues of intelligence collection
- Development and fielding of a new all-weather air defense gun system

The Army spends a great deal of money on Field Army Air Defense but gains little capability from it.

The committee found the following areas both well-directed and in-line with the Summer Study recommendations:

- Gap Crossing
- Earth Moving
- POL
- Containerization

Study the integration of all of the Command Post Services from a standpoint of mobility to allow the Command Post to set up or tear down in a minimum amount of time.

Specific Recommendations for the 1976 Stummer Study:

(1) Topic of Study should be more specific than 1974.

(2) Limit the number of groups.

(3) Eliminate weekend/evening meetings.

(4) Assign panel members in advance (two months).

(5) Consider "pre-briefings" on background, concurrent studies, so as not to intrude on Summer Study time.

(6) Organize the Study to keep briefings in the early part of the assessment to allow time for creative and productive efforts.

(7) A follow-up for each Study Group one or two months after the Summer Study would produce more Army activity than an Ad Hoc Review Group.

<u>Subject Possibilities for 1976 Summer Study:</u>

(1) Army systems and long-range plans

(2) The use of the spotter

(3) The use of the tactical computer

(4) The reduction of weight

ARMY SCIENTIFIC ADVISORY PANEL (ASAP) SUMMER STUDY 1974

Goal

The 1974 Army Scientific Advisory Panel (ASAP) Summer Study was convened to address two area of primary concern to the Army: (1) Opportunities for Technology Solutions to Mission Area Deficiencies; and (2) Ballistic Missile Defense in the Post Treaty World.

Mission Area Deficiencies and Opportunities (MADO) had six sub-areas: (1) Battlefield Surveillance and Target Acquisition; (2) Intelligence, Command and Control, and Communications; (3) Firepower; (4) Mobility Enhancement and Denial; (5) Survivability in Conventional CBR, and EW Environments; and (6) Field Army Air Defense. Ballistic Missile Defense (BMD) had two sub-areas; (1) Site Defense Follow-On After Prototype Demonstrations; and (2) Technology.

Methodology

Each group reviewed current and projected Army needs, questioned operational officers, development personnel, and analysts in an effort to find areas where suggestions or guidance might help the Army devise more productive R&D programs.

Results

The panel offered mostly operations-oriented recommendations concerning deficiencies/improvements in present or projected Army systems, very detailed and specific with less emphasis on technology base. No overall summary is included. Recommendations ranged from the philosophical: the Army should reassess the complexity, scope, and ambitions of Firepower concepts (TACFIRE, FADAC); to system specific: the Army should perform a comprehensive set of tests and analyses on various system configurations involving different data base and processor distributions (using TOS[2] and the then new advanced development QC's terminals) before finalizing the TOS design.

ASAP SUMMER STUDY 1976
- VOLUME 1 OF 6 -
ARMAMENT SYSTEMS SUBGROUP REPORT

Goals

1. Review the Science and Technology Objectives Guide (STOG) for fiscal year 77.
2. Assess the quality of laboratory plans by examining the degree to which "near term" system objectives of the technology base are supported.

Recommendations

1. Automatic Cannon for Anti-Armor Use

   - Continue support.
   - Evaluate rapid fire medium caliber guns systems for tactical utility when used to complement guided missile anti-tank systems.
   - Solve the problem of fabrication of high density penetrators with a technology plan.

2. Smoke and Observation

   - Determine common requirements for Services/DARPA in smoke development and field testing.
   - Assess the feasibility of alternate methods to produce smoke for the 8-14 micron band.
   - Establish use requirements for smoke protection.
   - Explore the use of pay loads or fuel-air explosives to disperse smoke.
   - Develop instrumentation for field testing of smoke and dust.

3. Indirect Fire Response Line

   - Reduce artillery response time; clarify system program objectives.
   - Include new target acquisition systems (e.g., SOTAS) in the definition of new artillery systems.
   - Focus the fragmented approach of the effort.

4. Line to Hit (Direct Fire)

   - Unburden the development of guided projectiles by eliminating arbitrary cost constraints while providing feasibility; examine trade-offs.
   - Define the battlefield conditions under which guidance must function effectively.
   - Integrate Direct Fire schemes with existing or planned tank fire control systems.

5. Scatterable Mines

- Continue development of a new family of mines.
- Emphasize techniques for hardening mines against CM's.
- Develop a high priority technology base mine program to assure active pursuit of new ideas.
- Use tactical employment studies to develop user guidance.

6. Survivability of Friendly Artillery

- Define a program to improve artillery survivability against Soviet threat.

7. Artillery Against Point Targets

- Study priority battlefield targets (e.g., air defense, artillery) as possible system concepts.
- Extend the experimental program aimed at the critical technical problems of the SADARM concept (e.g., target acquisition).

8. Forward Area Defense Gun Systems

- Accept the capabilities of the best off-the-shelf guns, ammo, radar, etc. to replace the inadequate arsenal since ROC of the above system cannot meet the requested deadline.
- Determine missions for AD systems in 1990's; configure programs based on current technology base programs.

ASAP SUMMER STUDY 1976
- VOLUME 2 OF 6 VOLUMES -
AVIATION SYSTEMS SUBGROUP

The subgroup addressed four areas of significance:

- AMRDL and its Flight Research Simulator
- RPV Program
- Human Factors/Behavorial Sciences
- Helicopter Weapons System Design Integration

General Recommendation

A "center of competence" should be established for the purpose of Weapons System Integration. This coordinated effort would be expected to focus the attention of the weapons systems design community, the airframe designers, the avionics community, and those conceived with human factors or system problems now inadequately addressed.

Specific Recommendations

Flight Simulator

Move target date for a flight simulator facility to optimize the nap-of-the-earth (NOE) mission helicopter and its associated system to 1979 from 1981.

RPV Programs

Funding and the schedule of this program grossly inadequate in relation to program objectives.

To remedy this situation:

1) Increase or reprogram funding of Aquila program

   - to ensure a sufficiently reliable system
   - to develop an in-depth program to determine RPV mission effectiveness.

2) Allow AVSCOM more time to test the reliability of Aquila systems prior to transition to user.

3) Have RPV component development programs address specific critical needs unearthed during initial testing phases.

4) Terminate/transfer to other line elements all RPV payload development if it does not directly support day or night target acquisition or designation.

Human Factors:

A unifying structure is necessary to review human factors; assign such responsibility.

Recommendations

1. S.T.O.G. and User Requirements

- Encourage interaction between user/laboratories to provide joint input to future STOGs.

- User agencies should study future system concepts with assistance from laboratories.

- Avoid tendency to "over specify" in STOG; do emphasize operational requirements.

2. Command and Control (C^2)

- Use 6.1/6.2 and joint DARCOM laboratories/TRADOC studies to explore new concepts for C^2 (centralized versus de-centralized systems).

- Consider the inter-relationship of Army C^2 system; must examine the need for information exchange.

3. EW Warfare

Deleted for security reasons.

4. ADP (Automatic Data Processing)

- Strengthen interaction between TRADOC planners and ECOM ADP system engineers.

- Develop a strong ECOM and BMD ADP liaison.

- Establish ADP System Engineering in ECOM's laboratories.

- Seek a more flexible concept for Fourth Generation Military Computer Family to allow substitution of hardware modules for software modules.

5. Tactical Communications

- Several recommendations relate to requirements to improve electronic vulnerability and flexibility of specific systems and cannot be provided because of security classification.

- Compare technical/tactical capabilities of newer and older beyond-line-of-sight connectivity (at moderate ranges)

  - mm wave/laser atmospheric scattering
  - satellites
  - artificial ionosphere
  - airborne relay.

ASAP SUMMER STUDY 1976
- VOLUME 4 of 6 -
MISSILE SYSTEMS SUBGROUP REPORT

Findings:

1. MICOM plan generally agrees with STOG elements

2. The technology base supports all STOG elements for MICOM plan except for addressing the all-weather and fire-and-forget technology. These requirements (in MICOM prior to STOG publication) are incompatible with weight constraint employed in the system concept.

Recommendations for Further Emphasis:

1. Close Combat, especially battlefield visibility

2. Fire Support (regarding WP artillery which outrages/outnumbers NATO artillery)

3. Air Mobility (reduce time required for target acquisition)

4. Air Defense (No program was identified as being underemphasized.)

Good Quality/High Relevance, but not directly supported by STOG:

1. Software development for complex weapons systems

2. Investigation of KE kill by missiles (need for feasibility study

3. Carrying an "eye-ball" with an RCM to an area of interest has been evaluated as feasible -- explore use in anti-tank indirect fire.

Work Not Being Done

Deleted due to security classification.

Discontinue Work

- Discontinue/reduce in favor of other programs.
- Advanced Multipurpose Missile Program
  - Use medium range anti-tank missile instead.
- Two Radar Programs in Air Defense (Hemispheric Dome, Quiet Radar)
  - Do not go past prototype.

ASAP SUMMER STUDY 1976
- VOLUME 5 OF 6 -
MOBILITY SUBGROUP

Methodology

Subgroup #5 adopted the Quadripartile Objective (QO) for Tactical Mobility (STOG 77). Only ground aspects of Air Mobility were considered. The study was divided into MERADCOM, TARADCOM, and the Army Corps of Engineers programs.

Recommendations

1. The following program should be cancelled:

   - Surface preparation to support heavy vehicles

2. The following programs are adequate and in accordance with STOG 77 and need no additional funds:

   - Specialty products for combat forces
   - Far-forward terrain survey
   - Fuels/lubricants
   - Electric power
   - Modeling and simulation for combat and tactical support vehicle systems
   - Test bed vehicles
   - Infinitely variable transmissions

3. The following mobility programs meet STOG 77 objectives, but need additional funding to meet systems development goals:

   - Barriers to enemy movement
   - Route and gap-crossing
   - Map production and dissemination
   - Terrain data updating
   - Counter-mine
   - Barriers for combat mobility support
   - Bridging for mobility enhancement
   - Containers/materials handling
   - Fuels handling equipment
   - High temperature, high-efficiency engines
   - External, self-contained suspensions
   - Tracks and wheels
   - Active and passive protection

4. The following programs need a new STOG review as well as additional funding:

- Improvements in Army Mobility Model (AMM)
- Modifications of AMM for tactical use
- Combat engineer equipment model
- Logistics over the shore
- Environmental control
- Advanced systems concepts for combat and tactical vehicle system
- Fuels for vehicle mobility

5. The following mobility Technology Base programs are adequately funded but need a re-vamped STOG:

- Camouflage/counter-surveillance
- Materials for vehicle mobility enhancement
- Combustion for mobility improvements
- Heat transfers and dynamics of vehicle mobility

ASAP SUMMER STUDY 1976
- VOLUME 6 of 6 -
SOLDIER SUPPORT SYSTEMS SUBGROUP

Findings and Recommendations

Overall, the STOG-77 lacks guidance as to when a capability is needed. Some STOG-77 items are so broad that almost any program can be considered responsive. It is recommended that STOG-78 items be sharpened in terms of time frame and specificity.

Specific Recommendations

A. Human Resources and Personnel Administration

1. Establish a program to meet future manpower concerns:

   - changing population distributions
   - impacts of changing economic conditions on recruitment/retention of personnel

2. Measure unit effectiveness in terms of leadership and management techniques.

B. Training

1. Add technical/scientific support to the following critical training areas:

   - Retention
   - Technology base for training devices and simulators
   - Large unit combat simulation
   - Technology base for field technical manual preparation
   - Modes of presentation other than the printed page

2. Increase support to simulation technology

C. Medical, Dental, and Life Support Systems

1. Incorporate more detailed STOG's in the biomedicine and health capability category

2. Emphasize these chemical/biological warfare concerns:

   - effects of chemical/biological agents
   - diagnosis of CB effects
   - potential vaccine protection
   - potential drug protection and/or therapy

D. Human Engineering and Performance Enhancement

1. Upgrade STOG to reflect the detailed and coherent human engineering program the Army needs.

2. Use human factors information much earlier in the system design and development cycle.

E. Food and Water

1. Address the technology base aspects (war and peacetime) of subsistence and food service systems.

2. Give higher priority to water purification, supply, and distribution in STOG's.

F. Clothing and Individual Equipment

1. The nuclear-biological-chemical (NBC) threat to the individual soldier must receive more detailed attention in the STOG.

2. The program that deals with the NBC aspects of soldier support must address:

- Individual clothing and equipment protection
- Decontamination equipment and procedures

G. Air Drop

1. Start efforts on equipment location and assembly aids.

2. Consider "stand-off" delivery systems.

H. Nuclear, Biological, and Chemical Warfare Protection

1. Incorporate NBC protection features in new designs, equipment, clothing, and shelters.

2. Develop a simple water kit to test for the possible presence of chemical agents.

I. Soldier Support Engineering

1. Establish and fund a 6.1 program for camouflage.

2. Include NBC protection as an integrated part of environmental control systems where applicable.

R

ARMY/AIR FORCE JOINT SUMMER STUDY
U.S. AIR FORCE ACADEMY 1978

GOAL

Address four topics identified by Tactical Air Command (TAC) and Training and Doctrine Command (TRADOC) as high-priority items for combined Air Force/Army attention:

- Reliable IFF of aircraft by ground-based AD systems
- Improved capability to provide supporting firepower by systems of either Service using target acquisition means of either Service
- Effective capability to interdict enemy command and control
- Accurate location and reliable classification by type, or identification by specific unit, of enemy AD systems.

METHOD

Four task groups, aligned to the specific goals, and looking to both the near term (up to 1983) and longer term (after 1983).

FINDINGS AND RECOMMENDATIONS

Each of the Task Groups addresed their topic area in terms of Allied Operations in the NATO Central Arena.

Task Group I: NATO Air Defense Environment for Aircraft Identification

Task Group I findings and recommendations are deleted due to security classification.

Task Group II: Supporting Fire for Friendly Forces

Task Group II findings and recommendations are deleted due to security classification.

Task Group III: Interdiction of Enemy Command/Control

Task Group III findings and recommendations are deleted due to security classification.

Task Group IV: Templating and Countering Soviet Defense on the Battlefield

Task Group IV findings and recommendations are deleted due to security classification.

Overall Recommendations of the Joint Study on C^3 in the NATO European Environment

Deleted due to security classification.

S

ODDRE PROJECT HINDSIGHT
OCTOBER 1969

Goals

(1) Determine which management factors are important to:

- Making research and development programs more productive
- Ensuring utilization of technology base program results.

(2) Measure the overall increase in cost-effectiveness, for current generation weapon systems, that can be traced to any part of the DoD investment in science and technology research.

(3) The strategies adopted to achieve these goals involved:

- Determining the extent to which new weapon systems are actually dependent upon recent advances in science and technology for their:
  - increase in system effectiveness
  - decrease in cost
  - increase in cost-effectiveness compared to a predecessor system.
- Determining the proportion of any new technology, required for attaining the above system improvements, that was a result of DoD-financed research in science and technology.
- Determining those significant management and environmental factors (as seen by the S&E research community) that lead to high utilization of research results.
- If there is, in fact, a strong reliance on new science and technology, devising a value - cost index which measures the return on investment research. This quantitative measure should be in terms of the enhanced cost-effectiveness made possible by the purchased knowledge.

Findings

For each strategy:

For Strategy 1: Markedly improved weapons systems result from skillfully combining a considerable number of scientific and technological advances.

For Strategy 2: More than 85% percent of new science and technology utilized in weapon systems resulted from DoD financed programs.

For Strategy 3: The utilization factor is insensitive to the classic policy/management differences between U.S. industry, DoD in-house laboratories, and university associated science and technology centers. It may, however, be sensitive to the differences in these types of organization and the classic academic organization structure of universities.

Most new technology utilized comes from research programs undertaken in response to recognized Defense problems. The scientist provides phenomenological explanations to the engineer who uses unified scientific theory and codified scientific information.

Research programs oriented toward specific types of equipment have been particularly successful in generating utilized knowledge.

Attainment of both a higher combined inventiveness and utilization rate is dependent on:

- the recognition of need,
- a source of ideas in the form of an educated talent pool,
- capital resources, and
- an adequate communication path to potential users.

For Strategy 4: Several factors refute the possibility of a simple or linear relationship between cost of research and value received, including:

- Pervasive use of one technology, if used in our systems, throughout many other systems.

- Improved weapon-systems or end-item equipments tend to be synergistic rather than cumulative consequences of the several embodied science and technology advances.

- The relative amount of new scientific or technological knowledge required to achieve greater effectiveness, lower cost, or improved cost-effectiveness of a new system increases with the technical complexity of a predecessor system.

- Therefore any crude approximation of measured value versus research expenditure is delusory. Return or investment will always appear greater where an improvement is made to a simple system.

DOD LABORATORY UTILIZATION STUDY (1975)

Goals

(1) Determine requirements for DoD laboratories.

(2) Assess the capability of the laboratories to meet these requirements.

(3) Identify excess capacity, overlapping capabilities, shortfalls, or instances where R&D could be contracted to industry at a saving.

(4) Define a program to upgrade the quality of the laboratories.

Specific Recommendations

Army:

- Restructure laboratories into a smaller number of development centers.
- Reorganize part of Army Material Command to simplify reporting chain for commodity command laboratories.
- Formulate and document a system for financial control on size of laboratories.
- Document the technology base program planning and approval authority.
- Enhance military R&D career pattern.

Navy:

- Reduce the redundancy in functions/platform assignments and inter-lab competition for funds.
- Change technology base management to correct fragmentation, uneven quality, and ineffective technology transfer.
- Improve utilization of Naval personnel.

Air Force:

- Increase 6.1 contract research program.
- Increase laboratory involvement in development through demonstration of end item feasibility.
- Amalgamate labs into centers allied with product divisions.

T

- Establish controls on labs in-house/contract ratio.
- Increase focus on C^3.

Conclusions and Recommendations

- There is a vital role for the laboratories not satisfactorily available from industry, universities, FCRC's, systems commands, etc.
- A formal laboratory comment on the technical risks of any new program should be required in the DCP/DSARC process.
- Laboratories should be operated by specifying only their maximum allowable level of in-house funding and leaving decisions on the mix and number of personnel to laboratory director.
- There is excessive in-house effort in the areas of materials and structures, electronics and weapons in both the Army and Navy and in the research area in the Army and Air Force.
- Number of in-house personnel working in the technology base should be reduced by 10% to 15%.

APPENDIX C

FIGURE OF MERIT ASSESSMENTS

This appendix serves as an audit trail of the Figure of Merit calculations for all of the technologies considered by the panel. A list of these technologies and a sample Figure of Merit assessment format precedes a tabulation of the results. These numbers are the basis for the determination of the Order of Magnitude Technologies shown in the main report.

ORDER OF MAGNITUDE TECHNOLOGIES
(CANDIDATES CONSIDERED)

DIRECTED ENERGY: Short Wavelength Lasers; Compact Efficient Chemical Lasers; Large Space Structures; Adaptive Optics; High Gradient Electron Accel; Pulsed Power; High Power Microwaves; Neutral Particle Beams; X-Ray Lasers (nuc-pumped)

RADAR TECHNOLOGY: Space Based Radar; Solid State Microwave Components

ELECTRO-OPTICS TECHNOLOGY: High Density Monolith EO/IR Sensor Systems; On-Board Data Processing (Clutter Suppression); Active EO-AO Filters; Space Coolers

COMPUTER SCIENCE: Supercomputers (including Advanced Algorithms); Advanced Software Techniques; Machine Intelligence (vision, speech understanding, inference and deduction, knowledge bases, natural languages); Education Technology; Optical Computers; Microprocessors Based Personal Training Aids; Distributed Data Bases

COMMUNICATIONS TECHNOLOGY: Secure Survivable Communications; Distributed Communications; Integrated Data, Text and Voice Networks; Packet Switching

MICROELECTRONICS: VHSIC; Non-Volatile Solid State Memories; Gracefully Degradable Chip Architectures; Optoelectronics

POWER AND PROPULSION: Adiabatic Turbo-Compound Engines; Homopolar Electric Drive Systems; Adiabatic Turbofan Engines; Superconductive Machinery and Switch-Gear; Laser Propulsion; Electromagnetic Propulsion; Space Power

PRODUCTION AND REPAIR TECHNOLOGY: Military Robotics; CAD/CAM/CAT; Flexible Mfg Technology; Distributed Information Process Control; Quantitative Nondestructive Evaluation; Net-Shape Processing; Space Fabrication Techniques

BIOCHEMICAL TECHNOLOGY: Genetic Engineering; Microencapsulation

MATERIALS: Advanced Composite Materials; Toughened Ceramics; Rapid Solidification Technology; Compound Semiconductors; Multiphasic and Layered Compounds; Optical Ceramics

SURVIVABILITY ENHANCEMENTS: Active and Passive Stealth; ECM Technology; Satellite System Hardening (Electronics); Low Cost INS

ASW: Non-acoustic ASW; Acoustic Arrays (Clear Day, FOSS); Active Sonar, Autonomous Submersibles

SPACE WARFARE: MHV; Antiground Space Weapon

STRATEGIC OFFENSE: Terminally Guided RVs

SAMPLE FIGURE OF MERIT FORMAT

Category	Criterion	High (9 pts) - Green	Med. (3 pts) - Yellow	Low (1 pt) - Red	Rating
IMPACT OR OPPORTUNITY	1) Mission Value	Strategic nuclear (offense and defense); space	Tactical Nuclear / Tactical Conventional	General support and logistics	
	2) Tech Impact on Mission/System	Raison-d'etre - system would not exist w/o this particular tech, order of magnitude improvement	Technology significantly affects performance	Generally affects performance	
	3) Pervasiveness	Across many missions and systems	Supports one mission or class of systems	Specific to one or a few systems	
	4) Nature of Impact	Revolutionary	Significant change	Evolutionary	
	5) Leverage (Exploits US/USSR Assymetry)	Gives capability to redress short term imbalance (e.g., CM present or projected system)	Redresses long term imbalances	U.S./U.S.S.R. force structures are compatible in size and sophistication for now and future	
	6) Simplicity	Could radically simplify weapons	Moderate influence	Little impact	
	7) Cost	Could radically reduce cost	Moderate influence	Little impact	
	8) Existence of Alternatives	No viable alternatives	Brute force could create an alternative	One or more exists	
	9) Duration of Impact	CM lower in cost could exist in >10 years	In <10 years	In <5 years	
				Total Oppotunity	

Category	Criterion	Low (1 pt) - Green	Med. (3 pts) - Yellow	High (9 pts) - Red	Rating
TECHNICAL RISK	1) Maturity of Technology	Mature technolgy	Still developing	Application uncertain, emerging	
	2) Technology Base	Principal technologies are practiced in DoD community	A "gap" exists: builds on current knowledge base	A "gap" exists: requires new knowledge base	
	3) Innovation Potential	DoD approach provides a significant performance advantage	More evolutionary in nature	DoD $$$ adds little since this is an area of strong technology competition	
SYSTEMS/ OPERATIONAL CONCEPT RISKS	1) Mission/System Related Risks	Similar concepts or systems to current DoD	Requires extensive application supports new systems/concept to DoD but one which is in existence	System/concept not in existence today	
	2) Political Bureaucratic Environment	Requires extension of existing system/treaties/ infrastructure	Requires displacement of mature tech or creation of as yet unperceived needs	Dependent on assets controlled by extensive infrastructures; requires change in arms control agreement	
	3) Level of Operational/ Support Impact	Can tap available personnel and/or support	Requires some unique skills/support	Requires significant shift in personnel and in support infrastructure	
R&D COSTS	1) Manufacturing Base	Builds on available base	Requires unique facility	Capital intensive and requires significant $$ expenditures key processes must be developed	
	2) Uniqueness of Military R&D	Primarily commercial, DoD exploits commercial developments	Selected aspects of technology are uniquely military	Uniquely military high R&D cost to DoD	
SUMMARY		Order of magnitude impact: high oppor./ low risk - mostly green	Mixed	Impact unclear/ mergies	
				Total Risk	
				Figure of Merit	

ORDER OF MAGNITUDE TECHNOLOGIES

	Very High Speed Integrated Circuits	Stealth	Advanced Software/Algorithm Development	Microprocessor Based Personal Training Aids	Fail Soft/Fault Tolerant/Self Policing Electronics	Rapid Solidification Technology	Machine Intelligence	Super Computers	Advanced Composite Materials	High Density Monolithic Focal Plane Arrays (Strategic)	High Density Monolithic Focal Plane Arrays (Tactical)	Radiation Hardened Electronics	Space Nuclear Power	High Power Microwave Generators (For Weapons)	Large Space Structures	Optoelectronics	Space Based Radar	Short Wavelength Lasers
IMPACT OR OPPORTUNITY																		
1) Mission Value	9	9	9	1	9	9	9	9	9	9	4	9	9	4	9	9	9	9
2) Tech Impact on Mission/System	4	4	9	4	4	4	9	9	4	9	9	4	9	9	9	1	4	6.25
3) Pervasiveness	9	9	9	9	9	9	9	9	9	9	9	9	1	9	9	4	9	9
4) Nature of Impact	6.25	9	9	6.25	4	4	6.25	4	4	9	9	4	9	9	9	1	4	9
5) Leverage (Exploits US/USSR Assymetry	9	9	9	4	6.25	4	4	4	1	4	4	4	4	9	4	1	4	4
6) Simplicity	9	6.25	9	4	9	4	6.25	6.25	4	1	4	1	1	4	4	4	4	4
7) Cost	9	6.25	9	6.25	6.25	4	9	6.25	4	9	1	4	1	4	6.25	4	4	9
8) Existence of Alternatives	4	4	4	2.25	4	4	4	4	4	4	4	4	9	4	4	4	4	4
9) Duration of Impact	4	9	4	4	4	4	9	1	4	4	1	4	9	4	4	9	1	9
TOTAL OPPORTUNITY	63.25	65.5	71.0	40.75	55.5	46.0	65.5	52.5	43.0	58.0	45.0	43.0	52.0	56.0	58.25	37.0	43.0	63.25
TECHNICAL RISK																		
1) Maturity of Technology	2.25	4	6.25	1	4	4	6.25	4	4	4	4	4	4	4	9	4	4	9
2) Technology Base	1	4	9	4	9	4	6.25	4	1	4	4	4	1	2.25	4	1	4	4
3) Innovation Potential	4	1	2.25	1	1	4	2.25	4	1	1	1	4	4	4	1	4	1	1
SYSTEMS/OPERATIONAL CONCEPT RISK																		
1) Mission/System Related Risks	1	1	4	4	4	1	4	1	1	9	1	1	4	9	4	1	4	9
2) Political Bureaucratic Environment	1	1	1	4	1	2.25	4	1	4	1	1	1	9	4	4	4	1	4
3) Level of Operational/Support Impact	1	1	2.25	1	1	2.25	4	1	2.25	9	2.25	1	4	4	9	6.25	4	4
R&D COSTS																		
1) Manufacturing Base	1	1	1	1	1	2.25	1		4	9	2.25	1	4	4	9	4	6.25	9
2) Uniqueness of Military R&D	2.25	9	4	1	4	1	4	6.25	4	9	9	9	4	9	4	4	9	9
SUMMARY																		
TOTAL RISK	13.50	22.0	29.75	17.0	25.0	20.75	31.75	24.5	21.25	46.0	24.5	25.0	34.0	40.25	44.0	28.25	33.25	54.0
Figure of Merit	4.7	3.0	2.4	2.4	2.2	2.22	2.06	2.1	2.02	1.26	1.8	1.72	1.5	1.39	1.3	1.3	1.3	1.2

APPENDIX D

BACKGROUND PAPERS ON ORDER OF MAGNITUDE TECHNOLOGIES

1. TECHNOLOGY: Very High Speed Integrated Circuits (VHSIC)

What is it? This development area covers technologies supporting design and architecture methods for laying out chips with up to 100,000 gates, providing the advances in lithography and processing necessary for 1.25 to submicron linewidths in fabricating such chips and demonstrating signal processing functions at the brassboard level.

Why is it important? What difference can it make? Such devices will enable a wide range of revolutionary military capabilities through their 100-fold increase in signal processing speed, greatly reduced cost per function, and lowered size, weight, and power. A summary of selected signal processing applications follows:

- Autonomous, adaptive satellite sensor and RPV sensor processing (IR, ESM, and radar)
- Anti-jam communications and radar systems with very wide instantaneous bandwidths
- Survivable, intelligent distributed processing
- Adaptive missile guidance with improved accuracy, recognition capability, and ECCM
- Real-time advanced acoustic array processing and rapid correlation and screening of multiarray data
- Adaptive navigation and guidance.

VHSIC technology offers greatly improved capabilities in self-test and repair, and offers simplified operation (transparent complexity).

What is the current status? The program has demonstrated the processing and lithography capability for 1.25μ features for silicon devices.

What is the current DoD program? The VHSIC program is a vertically integrated, tri-Service effort with FY 81 funding of $40M. DARPA also funds related technology and research (VLSI) ($21.6M).

What should the DoD program be? Although the VHSIC program is an aggressive effort aimed at end applications, there is a need for a more aggressive plan for early 6.3A demonstration to aid in the transition problem.

What are the measures of success? The VHSIC program should have three major criteria applied.

1. Technological: feature size (1.25μ to submicron); gates per chip (10^5); radiation tolerance; design flexibility
2. Processing power: 100-fold increase in throughput rate (5×10^{11} gate-Hz/cm^2)
3. Early technology insertion in key applications (e.g., A-J communications in three years).

2. TECHNOLOGY: Active and Passive Stealth

What is it? Stealth technology includes a range of techniques for reducing the signature of a vehicle or sensor to radar and optical surveillance systems. These techniques include active and passive methods: radar absorbing materials and structures, advanced designs/shapes, optical absorbers, techniques for reducing the emitted signature, and repeaters/transponders.

Why is it important? What difference can it make? Active and passive Stealth techniques are critical to successful penetration of advanced defenses for strike or surveillance missions, either strategic or tactical. Stealth enables survivable operation of high value platforms in a high threat environment. Such techniques are also crucial to cruise missile penetration and effectiveness. Stealth techniques have the inherent capability to counter high investment threat defensive surveillance capabilities.

What is the current status? Techniques have been developed for effectively reducing the signature of a strategic aircraft-sized platform for operation against advanced defense surveillance systems. Other techniques are being pursued for further reductions and for application to other systems (e.g., cruise missiles).

What is the current DoD program? Deleted due to security classification.

What should the DoD program be? The current program is adequate to exploit available technical opportunities. A greater emphasis is needed on early 6.3A demonstrations (6.3 "Technology Insertion" demonstration). For example, a full scale demonstration of a large Stealth aircraft could preclude too early a commitment to a strategic bomber based on the availability of Stealth techniques. Further, such a demonstration would define the effectiveness of U.S. air defenses to the Soviet deployment of Stealth techniques.

What are the measures of success? The most credible measure of success is actual measurement data of a signature collected on a full-scale aircraft or mock-up. A successful program would reduce the signature of a bomber-sized aircraft significantly across a wide spectrum of RF frequencies.

3. TECHNOLOGY: Advanced Software

What is it? This technology covers advanced software engineering techniques including software development tools, advanced higher level languages and operating environments, non-procedural languages, speech processing and recognition, and fast algorithms.

Why is it important? What difference can it make? The importance of software technology will increase as computers proliferate throughout the military and as microprocessing architectures become more complex. Software costs have risen to command 80-90% of the investment and life cycle costs of deployed computer systems and are projected to increase still further. Advanced software techniques can have an order of magnitude impact on such costs. Such advances will impact future capabilities for sustained operations, for near-real-time integration of the targeting and strike functions; for effective operation in heavy ECM environments, for complex battle management, and for tactical integration of space surveillance and targeting data. Cost effective software technology is crucial for:

- Assuring software portability (including operating systems)
- Fast software design, assembly, testing, and maintenance
- Growth over time (expansion, adaptation)
- Computational robustness and fault tolerance
- Automated programming.

Order of magnitude impact is projected for all of these performance attributes.

What is the current status? Software is early in its development as an engineering discipline. ADA, a standard language, has been developed for use throughout DoD. A wide variety of software development tools has been developed within industry. No standard operating system yet exists. There is as yet no coordinated, effective, tri-Service program pursuing high-leverage software advancements.

What is the current DoD program? The current DoD program in advanced software is estimated at $7M. The bulk of this effort is centered at DARPA. Most Service programs emphasize instruction set architectures and stereotype software applications. In nearly every case embedded software developments are lagging hardware developments.

What should the DoD program be? Because of its pervasive impact on future capability in all areas of warfare, this technology should be organized similarly to the VHSIC program. Further, the DoD program should be expanded to $30M to address the following promising opportunity areas:

- Fast algorithms development
- Efficient software portability
- Standard operating systems
- Survivable networking
- Echelons of computing
- Signal characterization for real-time interpretation
- Speech recognition and understanding
- Advanced life cycle management tools.

This program should be vertically integrated, managed by ASD(R&T), and critically coordinated among the Services. The creation of a separate line item to fence the funding may be appropriate.

What are the measures of success? The success criteria which should be used in measuring the evolution of advanced software and new faster algorithms should be:

1. Programmer productivity (order of magnitude impact within three to five years)

2. Software reliability and robustness

3. Software development costs (noticeable shift from the 90% costs embedded in military computer systems)

4. Enhanced processing throughput for widely used functions (e.g., Fourier transform and multipath correlations).

Detailed comparison standards should be developed as an early effort under this new program emphasis: also, a plan for system/application demonstration should be developed with certain applications being demonstrated as part of a vertically integrated program.

4. TECHNOLOGY: Microprocessor-Based Personal Learning Aids

What is it? This technology covers the application of microprocessors and the available commercial education and game software base (e.g., Plato) to individualized military personnel training. The technology base developments within this technology are of two kinds:

1. Development of relevant applications software.
2. Conducting training experiments of sufficient size to judge effectiveness.

Why is it important? What difference can it make? This technology can become a crucial part of troop training:

- The U.S. military has a serious problem recruiting technically literate personnel to operate advanced weapon systems.

- The present generation of Americans has been raised in an academic environment with a declining emphasis on science and mathematics. On the other hand, this generation is exposed to a culture with greatly enhanced receptivity to computer training (e.g., great exposure to television, personal calculators and computers, arcade games, smart games, etc.).

- Selected experiments in the commercial markets show order of magnitude results in use of microprocessors for learning.

- In future warfare the premium is on flexibility where rapid retraining of personnel will be crucial.

The criticality of this technology is high for training of military personnel for operations in advanced warfare environments: novel operating procedure, advanced maintenance techniques, new concepts for weapon employment, employment of EW Countermeasures, and continued operation in CBR and EW environments. In the EW area, the inadequacy of training has been detrimental both in terms of operational readiness and in terms of providing an increased understanding of the long term role of EW in warfare. The latter factor has been a major hindrance to the coherent evolution of EW. Success in this technology can lead to a significant reduction in training time (where such techniques are often the only realistic methods for training), a significant reduction training costs, and the achievement of higher skill levels.

What is the current status? There are a number of personal training aids and games now being marketed commercially (e.g., Plato). No similar set exists within the DoD.

What is the current DoD program? Although there is an aggressive technology base program in the general area of education technology, there is no identified support of microprocessor-based personal training. The focus of the current program is on large scale simulations for training in high skill areas. There is no program specifically aimed at the exploitation of microprocessors for training (a "Speak and Spell" for the military).

What should the DoD program be? What is needed is to find a way of pushing inexpensive microprocessors for training into the field. The DoD program should initiate experiments with new software and emphasize situations where quick results are very apparent. It is important not to get bogged down with large "statistically relevant" studies with large control groups, etc. A program of $4M is recommended to initiate this effort.

What are the measures of success? The key measure of success for this technology base effort is transitions to widespread use throughout various sectors of the military. A detailed plan of the targeted applications should be developed early in this recommended program. In the short term identify learning acceleration in a wide variety of field and laboratory experiments (one to three years). In the long term, perform more controlled experiments with cost analysis of training effectiveness (three to five years).

5. TECHNOLOGY: Fail-Safe, Fault Tolerant Electronics

What is it? This technology covers electronic sensors, computer systems (maxi, mini, or micro), and network techniques enabling continued operation with one or more functional components inoperative. Continued operation is accomplished by incorporating additional subsystems (components) and/or algorithms which, without external stimulus or resistance, ensure that occurrences of erroneous internal states do not result in internal failures. The techniques included provide a "self-policing" capability.

Why is it important? There is and will continue to be a pervasive use of advanced electronics systems throughout military warfare (sensors, computers, and networks). The complexity of operation of these systems and their poor reliability in the field have impacted their value in an operational environment. Techniques covered herein provide:

- Increases in electronic system availability and reliability, particularly in rugged environments
- Greatly reduced life cycle costs
- Simplified test and repair.

Such techniques can have a significant impact on operational readiness.

What is the current status? A range of techniques have evolved through commercial and university R&D. There is a significant commercial drive to develop such techniques for both microprocessors and complex computer systems and networks. Some techniques have evolved into military electronics.

What is the current DoD program? There is no central program in this technology, especially for the full range of tactical systems. The Air Force has a program in fault tolerant networks and electronics which emphasizes software techniques. An estimated $5M is being invested in fault tolerant techniques, spread throughout a large number of programs including the supporting technology phase of VHSIC.

What should the DoD program be? A centralized, vertically integrated program is necessary to fully exploit the potential of this technology. As with software, a VHSIC-like program can evolve a full range of systems with fail soft, fault tolerant characteristics for tactical and strategic applications. A $10M program which emphasizes tactical applications should be established.

The key areas for work are in modeling and analysis of networks and systems, techniques for automatic control or adaptive selection of degraded modes of operation, and near-real-time automatic reconfiguration.

What are the measures of success? Tactical demonstrations of such techniques with wide applicability should be selected. Detailed measure of success for such demonstrations should be developed:

- Equipment availability and reliability in the field.
- Degradation as a function of number of component failures.

6. TECHNOLOGY: Rapid Solidification Technology

What is it? Rapid solidification includes process technologies for producing powders which have been solidified at rates greater than 10^4°C/sec and which are suitable for consolidation into practical structural shapes. Research requirements include alloy development, dessaturation, and property measurement. Rapid solidification as a technology would also include incremental solidification of a metal deposit (powder or wire fed) on a substrate using laser or electron beam heating. Laser or electron beam heating can also be used for producing a melt pool on a surface for generating a self-quenched surface layer. Rapid solidification also includes melt spinning, a process which withdraws a rapidly-cooled filament or strip from a molten pool.

Why is it important? What difference can it make? Military applications of powder metallurgy include infantry armament; electrical distribution systems; more-durable jet engine, higher-thrust, light engines and airframes for increased thrust-to-weight ratios; and lighter-weight land vehicles. Materials made with rapidly-solidified powders are improved in almost every engineering property -- strength, toughness, fatigue, elevated temperature capability and corrosion resistance. The ability to produce components exhibiting such properties at lower cost, decreased strategic material input, and greatly improved durability is extremely critical to the overall performance of various military systems. The technology can be applied to most classes of materials to include superalloys, alloys of iron, aluminum, and titanium; refractory metals; ceramics; and metal-matrix composites.

What is the current status? The U.S. has a worldwide lead in the manufacturing scale processing of rapidly-solidified powders and powder products. However, there are a number of major scientific and technical questions that need to be resolved before large investments for commercial use of this technology can be made. Furthermore, a data base must be generated to satisfy designer needs.

What is the current DoD program? The total DoD program (Services and DARPA 6.1 + 6.2 + 6.3A) is $26.2M. Other U.S. agencies contribute around $6M more to this technology for a variety of potential non-DoD applications.

What should the DoD program be? This technology requires a major long range commitment by DoD and an effort to transition this technology to industry. The technology has an extremely high-payoff across-the-board for military equipment. An overall investment of approximately $200M over the next five years may be required to establish commercial sources of supply of RSR superalloys, aluminum alloys, and ferrous alloys currently under development.

What are the measures of success? This program will be successful if the following near-term (5-10 years) and far term (>10 years) goals are achieved:

Near Term

- A 150°F increase in the turbine-inlet-temperature capability of turbine blade superalloys is achieved.

- A 50% reduction in cobalt content of jet-engine, hot-core materials is demonstrated to be feasible.

- A 25% increase in the specific toughness and specific strength of airframe aluminum alloys can be achieved by RSR technology compared with current 2000 series alloys.

- A 100°F temperature capability of RSR aluminum alloys or current 2000 series alloys is demonstrated.

Long Term

- A factor of two or better life extension will be demonstrated through RSR technology in the following hardware categories:

  - Jet engine turbine and compression blades
  - High performance bearings
  - Reciprocating and diesel engine components
  - Airframe structures
  - Critical ferrous alloy structure exposed to erosive and corrosive environments.

- Superalloy turbine blades which will withstand turbine inlet temperatures of 3000°F or higher.

7. TECHNOLOGY: Machine Intelligence

What is it? This technology is the know-how for heuristic programming and focuses on advanced computer-based systems having adaptive, decision-making characteristics, including techniques for data filtering, multisensor correlation and integration, and automatic adaptation to unanticipated situations. This technology can furnish system with broad knowledge of acts and strategies for dealing with any specific problem or with a class of problems. This general approach can lead to systems with far greater adaptability, flexibility, and survivability than can be achieved with more conventional designs. It also provides for a more natural man/machine and man/software interaction.

Why is it important? What difference can it make? Machine intelligence offers the promise of a wide range of military capabilities including:

- C^2 and Crises Management - Self-adapting software systems are able to make significant changes in their internal processing logic in response to user commands or based on past demands which have been placed on the system. Coupled with speech processing, a commander can interrogate, in ordinary English, a set of distributed computerized data bases to form an assessment of his own assets or to test the feasibility of a contingency plan.

- Autonomous Weapon - A cruise missile, torpedo or mine incorporating machine intelligence can accomplish some of the functions normally performed by manned systems. A "smart" RPV, for example, can make adjustments in the prosecution of its mission based on an iterative process of sensor updates and "decision" points integrated into its computer logic. Such an autonomous weapon can be made impervious to conventional jamming.

- Automatic Programming - Computer software is a multibillion dollar expense in defense procurements and operations. It should be possible within the next 20 years to make quantum improvements in verifying the consistency of programs with specifications based on a machine intelligence methodology. The cost savings can be enormous.

- Expert Data Bases - The use of expert data bases in tactical operations can provide revolutionary improvement in the effectiveness of decision making in high stress environments.

What is the current status? Machine intelligence, as a science is at a very early stage of development. There are currently only 250 qualified scientists and engineers in the country with approximately 25 project leaders. Training is centered in three premier universities (MIT, Standford, and Carnegie-Mellon) with 12 second-tier universities producing 10-20 PhDs annually. The industry/DoD demand is greater than the supply of expertise and the situation is getting worse.

What is the current DoD program? DoD agencies sponsor some $13.2M annually for contract work with negligible in-house work. The focus of this work is on basic research with little emphasis on the military applications. NPG in Monterey offers a course in machine intelligence methods.

What should the DoD program be? The DoD program should be increased to a total of $25M including the following reorientation:

1. Concentrate on a few technical areas - modeling, generic expert systems, cooperative and distributed systems, and large data base management systems.

2. Focus applications - tactical assessment, distributed weapons control, software verification.

3. Manpower and training - train military personnel for machine intelligence development and application through in-service programs and university training. Develop management-level and command-level seminars.

4. Focal point for machine intelligence center - create a synergistic mechanism for exploiting machine intelligence for military use managed by OSD.

What are the measures of success? This program would be successful if at least one significant new defense application of machine intelligence per year can be achieved after 1985 and if the number of defense personnel trained in machine intelligence methodology doubles every three years after 1983. Significant Service involvement is required at the outset to focus the early demonstration on the most important applications.

8. TECHNOLOGY: Supercomputers

What is it? This technology covers advanced processor developments (including pipeline, parallel, and multiprocessors). Although advanced devices such as optical and cryogenic provide significant improvements in computer performance, they are not included under this category. The critical technology included is in architecture development. The most important architectures are those which incorporate VLSI/VHSIC hardware and which include solution to problems of timing, partitioning of functions, and interfaces for systems with a throughput greater than 100 MIPS.

Why is it important? What difference can it make? Advanced computer architectures permit revolutionary improvements in computer system and/or performance across a wide range of military systems, both strategic and tactical:

- Advanced towed acoustic array processor
- BMD radar
- Advanced hydrodynamic and aerodynamic modeling
- Advanced cryptography and intelligence exploitation techniques
- Large scale simulations.

The performance impact in the above systems will include higher computational throughput; broadband high resolution signal processing; compactness (for a given computer capability); and automatic programming.

What is the current status? The S-1 uniprocessor has been completed and a demonstrated to have a throughput of 10 MIPS. A 4x4 multiprocessor will be demonstrated within two years with throughput of up to 400 MIPS.

What is the current DoD program? The only supercomputer program (outside of those which evolve from the VHSIC program) sponsored by DoD is the S-1 program ($9M).

What should the DoD program be? Due to the importance of the impact of supercomputer technology on future U.S. capability, an aggressive program is needed to capitalize on the available technical opportunities. The current S-1 program moves in that direction but is not representative of potential revolutionary technical improvements needed for the critical military applications. A wider range of techniques should be sponsored. A total program of $15M is needed for this effort. The Congressionally mandated S-1 program is focusing only on one set of techniques. This focus is not in the best interest of the country.

What are the measures of success? Three demonstration efforts should evolve from this program within two to three years:

- Large scale modeling and simulation demonstration (> 400 MIPS)
- Cryptography demonstration (x 100 better than current computer systems)
- ASW inter-array processing (10 Giga IPS)
- BMD radar processor (x 10 faster computation of key functions).

9. TECHNOLOGY: Advanced Composite Material

What is it? Advanced composite materials include graphite-reinforced organic matrix, carbon-carbon, metal matrix, and ceramic matrix composites. These materials are comprised of high modulus, low density, high strength filaments embedded in a compatible matrix imparting mechanical continuity and compatibility. The fibers can include boron, carbon, polymers, silicon carbide, alumina, etc. Matrix materials include polymers (epoxy, phenolic, nylon, polymide, etc.), metals (Al, Mg, Ti, Pb, etc.), carbon, and ceramics.

Why is it important? What difference can it make?

1. Organic-Matrix Composites in Airframes and Missiles - Organic composites will revolutionize the airframe industry. Weight savings translate directly into increased range, maneuverability, and payload. The AV-8B which contains a higher amount of composites than the AV-8A can carry two to three times the payload and have two to three times the probability of kill on most missions. Composites are found in tactical aircraft, TRIDENT, Minuteman and the IUS. There are also numerous potential applications in tactical vehicles, marine platforms and materials handling systems.

2. Carbon-Carbon - These materials are used in re-entry vehicle nose tips and ICBM rocket nozzles. Materials performance strongly affects the re-entry accuracy of strategic offensive missiles. Technology-base-developed fine weave carbon-carbon materials are prime candidates for the next generation of RVs.

3. Metal Matrix Composites - These materials will find wide application in aircraft, missiles, spacecraft, armaments, and ordnance. Major weight savings and dimensional stability are provided by MMC. Large structures in space will be highly dependent on MMC developments.

What is the current status? Organic matrix is finding wide application in industry. Lear Aviation has developed an all composite aircraft. Carbon-carbon and metal matrix are military-dominant technologies. These composites have been demonstrated in a number of strategic applications.

What is the current DoD program? Organic matrix funding is $34M, carbon-carbon is $13.3M and metal matrix is $19.7M. The total is $67.0M.

What should the DoD program be? Technology base funding for organic matrix is a major portion of the total DoD advanced composites program. This effort may be too high for 6.1/6.2 since such composites are finding wide application in military and commercial aircraft. Some portion of this R&D should be included within the various airframe programs. In carbon-carbon, continued development of advanced nose tips and heat shields will probably lead to significant RV accuracy improvement. Technology base funding is adequate for carbon-carbon. For metal matrix, feasibility of major gains in military capability has been demonstrated in the laboratory but technology base funding is tight. A greater level of effort in manufacturing technology is essential.

What are the measures of success? The following near-term goals should be obtained:

- Carbon-Carbon Composites

  - Demonstrated thermal protection for MX and D-5 MK-500 Maneuvering Re-Entry Vehicle

  - Demonstrated all-weather RV capability

- Metal Matrix Composites

  - Demonstrated performance improvements (weight savings, dimensional stability, fatigue characteristics, higher temperature operation, no contamination, improved radiation survivability) as outlined below:

    1. Missile components (30% weight savings in upper stages which provide increased range in strategic missiles; tactical missile components with higher temperature operation, extended range/payload, missile fins with 60% weight reduction).

    2. Materials for mines and torpedoes with deeper depth capability (10% increase in depth capability).

    3. Aeropropulsion components with higher operating temperatures and tip speeds; 10% thrust/weight improvement.

    4. Weight savings and dimensional stability in important structures; spacecraft, airframe, shipborne and spaceborne antennas, laser mirror substrates (100% improvement in beam capability).

10. TECHNOLOGY: High Density Monolithic Focal Plane Arrays (FPA's) (U)

What is it? This technology covers Mosaic sensor arrays for optical through IR operation where the detectors, first stage signal processor, multiplexer, and output preamplifiers are within a monolithic structure. The technology includes extrinsic silicon, hybrid InSb-Si, and HgCdTe arrays. Advanced coolers for space applications are also covered within this technology.

Why is it important? What difference can it make? The combination of EO/IR FPA's with monolithic devices for detection and processing enables dramatic improvements in sensor performance (real time, onboard, adaptive processing of data for $>10^6$ FPA elements allowing high sensitivity, high resolution, and coverage over large areas in a single sensor.

- Strategic Attack Assessment: Early detection for maximum response time; provide targeting data on RV impact points for hand-off to defense.
- Launch-Under-Attack Retargeting: Post-attack assessment and retargeting for hand-off to inflight ICBM/SLBM.
- Very High Resolution Space Surveillance
- Spacebased Real-Time Targeting of High Altitude Strategic Aircraft (with future potential to detect low altitude aircraft and perhaps cruise missiles).
- Near-Real-Time Theatre and Ocean Surveillance/Targeting
- A wide array of tactical EO/IR capabilities (e.g., passive search, cruise missile guidance).

Monolithic FPA's also provide real-time effective clutter rejection and MTI capabilities. This technology is crucial in future tactical scenarios which require long range surveillance (seeing deep), near-real-time integration of target acquisition and strike, tactical use of space, and sustained warfare (> 72 hours).

What is the current status? Status deleted due to security classification.

What is the current DoD program? The current program is $102M, mostly under the DARPA/STO program ($77M of 6.2 in the DARPA and Services, and $25M in 6.1). The program consists of system level proof of concepts in space application, technology demonstrations (Si-X, HgCdTe arrays), and phenomenology research (target, backgrounds).

What should the DoD program be? No change in the program is needed. Continue with the current high magnitude program to ensure success in the planned demonstration programs.

What are the measures of success?

1. System Demonstrations

   Details deleted due to security classification.

2. Technology Demonstrations

   Details deleted due to security classification.

3. Phenomenology

   Details deleted due to security classification.

11. TECHNOLOGY: Radiation Hardened, Advanced Electronics

What is it? This technology covers materials processing and special design considerations for hardening electronic components, subsystems and systems against natural (e.g., space) or artificial (e.g., radiation, EMP) environmental effects. This technology also includes the necessary test facilities and instruments for measuring vulnerability.

Why is it important? What difference can it make? This technology is critical for military system survivability in current and expected future military operations, particularly in nuclear warfare or in scenarios involving directed energy weapons. Satellite and other space systems, an increasingly important element of military operations, are particularly soft. Similarly, the trend toward wide exploitation of VHSIC technology presents a significant challenge to hardening designers. The expected reliance on VHSIC raises the importance of hardening know-how.

What is its current status? Details deleted due to security classification.

What is the current DoD program? The current DoD program for hardening of advanced electronics is fragmented and spread among many efforts (AFML, NRL, NSWC, etc.). The EMP radiation, laser and microwave vulnerability and hardening efforts are handled under separate programs.

What should the DoD program be? A much greater emphasis on advanced sensor/processor hardening is needed. Further, a central focal point assigned the responsibility for coordinating the work of all three Services and DARPA is essential for such an effort to preclude unproductive redundancy. This program should be initiated at a level of $15M.

What are the measures of success? The key measure of success is a demonstrated increase in hardness sufficient to meet the JCS requirements for:

- Spaceborne IR sensor
- Spacebased radar
- Spacebased communications/navigation
- VHSIC tactical processor

12. TECHNOLOGY: Space Nuclear Power

What is it? This technology covers reactor techniques necessary for achieving power levels greater then 50KW or greater. Such techniques include but are not limited to those incorporated in the LASL space reactor system.

Why is it important? What difference can it make? Many future military space systems require high power (> 50KW) and greater survivability than currently available:

- Spacebased radar
- Directed energy weapons
- Man in space for military missions
- Multipurpose IR battle management systems.

Nuclear reactor technology is inherently strong in both attributes. It provides an order of magnitude advantage over competing solar techniques in the cost of delivered spacecraft power above 50KW and is significantly harder against the expected radiation environment.

What is its current status? Details deleted due to security classification.

What is the current DoD program? There is no DoD program in this technology. DoE is supporting work at LASL at a minimal level of effort. This work supports the development of advanced heat fuses and high efficiency, thermo-electric conversion techniques (particular emphasis on materials R&D).

What should the DoD program be? A meaningful demonstration program is needed for a 50-100KW reactor to ensure the availability of the necessary power for essential future space capabilites. The level of effort and timing for such a program are uncertain.

What are the measures of success? The key measure of success is the full scale demonstration of a space reactor of 50-100KW within five years.

13. TECHNOLOGY: High Power Microwaves

What is it? High power microwave generator technology covers methods for generation and focusing of intense RF power (pulsed or CW) at high frequencies (cm-mm Wave) as well as the phenomenology of interaction of intense microwave radiation with materials, sensors, and electronics. The key source technologies are gyrotrons, relativistic magnetrons, and free electron lasers operating at RF frequencies.

Why is it important? What difference can it make? The high radiance levels made possible by recent advances in high power, short wavelength microwave generators will likely enable effective mobile tactical microwave weapons as well as significant extensions of more conventional applications.

- The potential for sensor and electronics damage at useful operational ranges (systems hardened to practical limits are believed to be engaged at ranges on the order of 15-20 km)
- Unconventional anti-personnel weapon
- Conventional jamming at greatly increased standoff ranges
- Longer range mm wave radar capability with high resolution, low multipath clutter, low probability of intercept, and resistance to jamming.

What is its current status? Almost no vulnerability data exist for tactical missiles and electronics at the high frequencies and power densities of interest. The effectiveness of various hardening techniques is likewise unknown. Developmental devices have achieved giaawatt peak powers and 100's of Kw average power at cm to mm Wave frequencies.

What is current DoD program? There is no DoD program pursuing Tactical Microwave Directed Energy Weapons. The DoD program for high power microwave generators is embodied in the advanced microwave jammer program ($20M). In addition, the Navy has a $0.6M directed energy weapons program.

What should the DoD program be? Due to the high potential of high power, short wavelength microwave generators as an anti-sensor/electronics and anti-personnel system and the need to understand the vulnerability of U.S. sensors and electronics, greater emphasis is needed on the directed energy applications. A program of $5-10M is needed to rapidly address target vulnerability and hardening techniques. The devices themselves are adequately supported at the present time.

What are the measures of success? The major uncertainty for this technology is the vulnerability of various systems at the high frequencies adn the effectiveness of hardening techniques. These questions should be answered experimentally for representative targets within three years and the results generalized to broader classes of targets and representative application scenarios to assess effectiveness.

14. TECHNOLOGY: Large Structures in Space

What is it? Large-scale, deployable, and erectable space structures will require highly innovative structural design and materials. New engineering concepts are needed to satisfy an increasingly complex mix of requirements for maximum rigidity and minimum weight; control of structural, thermal, and environmental loads; high survivability (against nuclear, laser, and particle beam threats); elimination of creep and relaxation during storage; and ease of space erection, joining, and proof testing. Optimal structural design concepts for zero gravity are likely to be dramatically different than those employed on earth. New methods for employing stored energy and memory materials (reversibly transformable) will be sought to ease the space erection burden. Active structures (with sensing and feedback) are needed for advanced optical and radar systems.

Active structures and adaptive optics technology are included within this technology. Adaptive optics technology covers all methods of compensation for non-uniformities or turbulence within an optical train. These techniques can compensate for atmospheric turbulence, for optics deformation, or for poor beam quality.

Why is it important? What difference can it make?

1. Directed Energy - Particle beam and high energy lasers in space require relatively large structures to accommodate focusing devices and in the case of high energy laser, large sensors. High dimensional stability is required for pointing and tracking. Adaptive optics techniques can provide an order of magnitude improvement in capability for a space-based high energy laser system or for optical sensors (ground-based EO/IR sensors for detection and location of targets within the atmosphere). Several orders of magnitude improvement is projected in resolution or in energy on target. For a space-based high energy laser weapon system, the improvement in energy on target has a significant impact on the size of the total system, a major cost factor.

2. Radar - With the advent of the shuttle, it is conceivable that very large radar systems can be deployed in space in monostatic and bistatic modes. Such radars can be used for a variety of functions:

   - Detection/Track Radar for Land and Ocean Surveillance
   - Multi-Mission Radar
   - Multistatic Missile Detection Radar

3. Surveillance/E-O - Exploiting the sensitivity of the mosaic focal plane arrays requires large optics. Possible future systems include:

   - ICBM Detection and Tracking System
   - High Altitude Air Vehicle Detection System
   - Theatre and Ocean Surveillance System

What is the current status? As discussed above, adaptive optics techniques can be critical to such capabilities. A number of technical assessments and preliminary design studies have been conducted. No major demonstration projects are underway. The adaptive optics techniques under development are emphasizing the laser weapon applications. There have been laboratory demonstrations of an order of magnitude improvement in energy on target through atmospheric turbulence (up to a fundamental limit).

What is current DoD program? There are no DoD programs aimed specifically at this technology outside of adaptive optics. Many other programs are supportive (e.g., metal matrix composites). NASA has programs aimed at building lightweight structures from metallic ribbons. The NASA program is $18M. The estimated size of the current DoD effort in adaptive optics is $6M.

What should the DoD program be? The current adaptive optics program is of adequate size to exploit available technical opportunities. Some work is needed to emphasize sensor applications in addition to laser weapons applications. In other large structure areas the DoD program is not adequate. There is a need to define a series of demonstrations for future joint NASA/DoD undertaking.

What are the measures of success? The adaptive optics program must provide credible performance demonstrations in time to be integrated with IR monolithic FPA demonstration and with high energy laser demonstrations. A key area of concern is the availability of the necessary space transportation capability. A well thought-out plan for the evolution of such structures should be prepared within DoD (six month effort).

15. TECHNOLOGY: Optoelectronics

What is it? Optoelectronics (often termed integrated optics) is the technology for integrating optical sources, switches, waveguides, modulators, multiplexers, lenses, beam deflectors, and couplers on a single chip. The two basic material systems for emitters and detectors are III-V compound semiconductors and dielectric crystals (such as $LiNbO_3$ and $LiTaO_3$). Waveguide materials include CO_2, glass, polymer, and compound semiconductors.

Why is it important? What difference can it make? Optoelectronics provide a number of clear advantages for military communications and signal processing:

- Very high data and switching rates
- Immunity from EMI, EMP, ground loops
- Rugged, compact, and low cost devices.

For military communications, optoelectronics provides optical switch rates and throughput for data buses, computer/LSI interconnections, and networks. In signal processing, optoelectronics enables a very broadband high resolution acoustic, ESM, and spectrum analysis capability; high speed A to D conversion; broadband correlators and delay lines; programmable filters; and laser gyro interferometers. Due to their ruggedness, cost, and size, such devices are mission enabling in satellites, missiles, and aircraft.

What is its current status? An RF spectrum analyzer using an optoelectronics device has demonstrated a 30 db dynamic range and 400 MHz bandwidth.

What is current DoD program? The current program includes both device technology efforts and several demonstration projects (ESM, A to D conversion). The total budget is contained within the Fiber Optics Program which is estimated at $15M.

What should the DoD program be? No changes are needed in communications application. Expansion of computer related high throughput applications.

What are the measures of success? The current effort should produce the following demonstrations of capability within three years:

- RF Spectrum Analyzer (1GHz; 40 db dynamic range)
- A to D Convertor (> 1 GBPS)
- Laser Gyro Interferometer (< .0001°/hr)
- Programmable Filters and Correlators.

16. TECHNOLOGY: Space-Based Radar

What is it? The key technologies encompassed under this category include advanced solid state microwave devices (preferably three terminal FET amplifiers), advanced antennas, and novel signal processing techniques for greater onboard autonomy.

Why is it important? What difference can it make? This technology can provide a near-real-time surveillance and targeting capability with:

- Day/night and "all weather" operation
- Worldwide coverage
- Support of tactical and strategic operations over land and at sea.

Techniques to be developed are those enabling:

- More reliable operation
- Higher resolution capability
- Greater ECCM techniques capability
- Lower unit costs.

These areas of performance growth are crucial to meet the demands of future land and naval scenarios.

What is the current status? Space-based radar systems have been configured for low earth orbits (primarily for naval applications and TACAIR). No U.S. decision has been made to deploy such a system even though the Soviets have done so. The U.S. hesitancy stems from the unclear performance advantage of a space-based radar system based on current technology versus OTH-B.

What is the current DoD program? Low level study and trade-off efforts are underway within the Navy, Air Force, and DARPA. DARPA also has a technology program for advanced antennas and onboard processing. The Navy and Air Force have relevant component technology efforts. An estimate of the combined magnitude of these efforts is $8M.

What should the DoD program be? The current program seems reasonable until the technology has been developed to allow design of a "technology insertion" demonstration program.

What are the measures of success? The key measures of success are:

- Component performance
  - Solid state device (power, noise, figure, and reliability)
  - Antenna designs with adequate performance (gain, weight)
  - Onboard processing (demonstrated autonomous capability)
- Definition of viable space-based radar systems based on proven technology
- Full-scale demonstration and test of a prototype.

17. TECHNOLOGY: Short Wavelength High Efficiency Lasers

What is it? This technology encompasses high average power lasers which operate at wavelengths of order 1 micron or shorter, with high efficiencies of order 10% or greater, as well as the sub-microradian pointing and collimation beam control technology for their use both through the atmosphere and in space. The laser concepts which currently are covered include free electron lasers, excimer lasers, metal vapor lasers, and iodine lasers.

Why is it important? What difference can it make? Short wavelength lasers have the potential for enabling key strategic applications:

- Submarine Laser Communications
- Ground-Based ASAT
- Strategic Space Weapons.

What is the current status? Current achieved performance in the laboratory:

- Excimer - XeF - demonstrated in the laboratory up to the kilojoule level
- Free electron laser - gain in visible and oscillation at 3.8 microns demonstrated; high efficiency experiments in process.

What is the current DoD program? The major programs are:

- Weapons oriented

-- Free Electron Lasers (DARPA)	$ 2.9M
-- High Power Vis. Lasers (DARPA)	$ 5.4M
	$ 8.3M

- Blue Green Lasers/Communications Oriented (Not directly applicable or scalable to weapons)

-- Blue Green Lasers (Navy)	$ 2.0M
-- Submarine Laser Comm. (DARPA)	$11.0M
(space-based and/or relay)	--
	$13.0M

What should the DoD program be? The weapon oriented portion of this program is subcritical given the enabling nature of this technology. The currently planned funding profile should at least double to allow both free electron lasers and excimers to be brought to a decision point within 3 to 4 years. In addition, beam control technology specific to short wavelength lasers is a critical technology which should receive adequate funding during this time period. The blue-green laser programs (for communications with submarines and other underwater applications) appear adequately funded.

What are the measures of success? They key success criteria for weapon oriented programs should be:

- Laboratory demonstration of scaling and average power for both excimer and free electron lasers to allow decision within 3-4 years for best candidate to scale to weapon level power and efficiency.

- Laboratory proof of principle experiments completed for key beam control issues

- Confident hardening assessment data for ICBM booster in this time frame.

APPENDIX E

SOME ALTERNATIVE FIGURE OF MERIT CALCULATIONS

-- A NOTE OF CAUTION --

APPENDIX E

SOME ALTERNATIVE FIGURE OF MERIT CALCULATIONS

In order to understand the sensitivity of the "Figure of Merit" results to the numerical weightings, several alternative weighting schemes were calculated. The attached table shows the result of these calculations. The first column on the table is the weighting actually used by the panel. Columns 2 through 5 are the alternatives. As seen in this table, the actual numerical values change drastically and the priority ranking changes to a lesser degree. Because of this sensitivity, the reader should not use the actual numbers as a direct measure of "value" nor should he attempt to use the order of the "Top 17" in decisions. The key conclusion to draw from the Figure of Merit analysis is that these 17 technologies are very important to the U.S. military and should be aggressively pursued.

ALTERNATIVE FIGURE OF MERIT CALCULATIONS

TOP "17" TECHNOLOGIES	$\frac{\Sigma O}{\Sigma R} = \frac{9,4,1}{1,4,9}$	$\frac{\Sigma O}{\Sigma R} = \frac{3,2,1}{1,2,3}$	$\frac{\Sigma O}{\Sigma R} = \frac{27,8,1}{1,8,27}$	$\frac{\Sigma O}{\Sigma R} = \frac{9,4,1}{1,2,3}$	$\frac{\Sigma O}{\Sigma R} = \frac{3,2,1}{1,4,9}$
Very High Speed Integrated Circuits	4.7	2.4	8.8	6.3	1.7
Active and Passive Stealth	3.0	2.0	3.8	5.5	1.1
Advanced Software/Algorithm Development	2.4	1.7	3.0	4.9	.84
Microprocessor Based Personal Training Aids	2.4	1.7	3.2	3.7	1.1
Fail-Soft/Fault-Tolerant/Self-Policing Electronics	2.2	1.7	2.6	4.3	.88
Rapid Solidification Technology	2.2	1.6	3.0	3.7	.96
Machine Intelligence	2.1	1.5	2.7	4.2	.76
Super Computers	2.1	1.6	3.0	4.0	.86
Advanced Composite Materials	2.0	1.5	2.7	3.4	.89
High Density, Monolithic Focal Plane Arrays	1.8	1.5	2.2	3.5	.78
Radiation-Hardened Electronics	1.7	1.5	1.9	3.3	.76
Space Nuclear Power	1.5	1.3	1.9	3.3	.59
High Power Microwave Generators	1.4	1.3	1.5	3.2	.55
Large Space Structures	1.3	1.3	1.4	3.2	.51
Optoelectronics	1.3	1.2	1.3	2.6	.60
Space Based Radar	1.3	1.2	1.3	2.7	.57
Short Wavelength Laser	1.2	1.2	1.2	3.1	.44

APPENDIX F

DESCRIPTION OF THE NOSC EXPERIMENT

APPENDIX F

DESCRIPTION OF THE NOSC EXPERIMENT

This description is taken from a detailed explanation of the experiment as found in the Federal Register of 18 April 1980 (Vol. 45, No. 77, pp. 26505-26554).

The demonstration project plan as approved by the Office of Personnel Management reads as follows:

An Integrated Approach To Pay, Performance Appraisal, and Position Classification for More Effective Operation of Government Organizations

A Plan for a Demonstration Project Authorized by Title VI of the Civil Service Reform Act of 1978

Prepared by Naval Ocean Systems Center, San Diego, California 92152. Naval Weapons Center, China Lake, California 93555

Executive Summary

The enclosed plan is submitted to the Office of Personnel Management as a demonstration project designed to improve the performance of federal employees, as authorized by Title VI of the Civil Service Reform Act (CSRA). For the reader's convenience, a broad summary of the information contained in this plan is provided below. For more information, the reader is referred to corresponding sections of the report.

Purpose

The purpose of the project is to demonstrate that the effectiveness of federal laboratories can be enhanced by allowing greater managerial control over personnel functions and, at the same time, expanding the opportunities available to employees through a more responsive and flexible personnel system. In order to accomplish this purpose, changes are proposed that include (1) a more flexible, manageable, and understandable classification system; (2) a performance appraisal system that links performance objectives, compensation, and organization effectiveness; (3) an expanded application of the merit pay concept; (4) recognition of demonstrated individual performance in the reduction-in-force (RIF) process; and (5) the use of suspended penalties in certain adverse action situations. Together these changes can help managers to operate with more authority, responsibility, and skill to increase work force and organizational effectiveness and efficiency.

Participating Organizations

The Naval Ocean Systems Center (NOSC), San Diego, and the Naval Weapons Center (NWC), China Lake, Calif., will be joint participants in the project. The School of Public Administration, University of Southern California, Los Angeles, will serve as an independent project evaluator. The Office of Personnel Management (OPM), including the Western Regional Office, will provide assistance to the project, as will components of the Department of the Navy.

Types and Numbers of Participating Employees

The initial increment will comprise all technical professionals (GS-5 through GS-15) and all other GS-13 through 15 employees, as shown in Table 2, at the two participating Centers. Additional categories that may be included subsequently are technicians and administrative professionals below GS-13 and clerical personnel. The basic increment will include 1,500 employees at each of the two Centers.

Methodology

This plan spells out the methodology to accomplish over a 5-year demonstration period the following specific changes: (1) five levels of classification; (2) broad pay bands within classification levels, with individual placement into one of five basic incentive pay groups; (3) development of general classification/performance standards; (4) performance appraisal based on Performance by Objectives; (5) reduction-in-force procedures that emphasize performance while substantially retaining existing ranking factors; and (6) the use of suspended penalties in certain adverse action situations. Figure 1 illustrates the pay and performance changes of this plan.

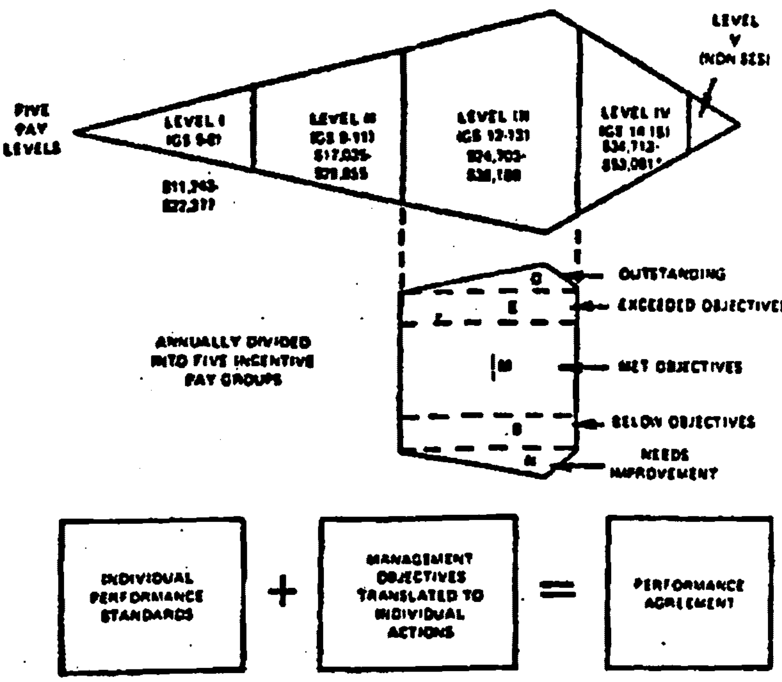


FIGURE 1. Pay and Performance Plan.

*SUBJECT TO STATUTORY LIMITATION

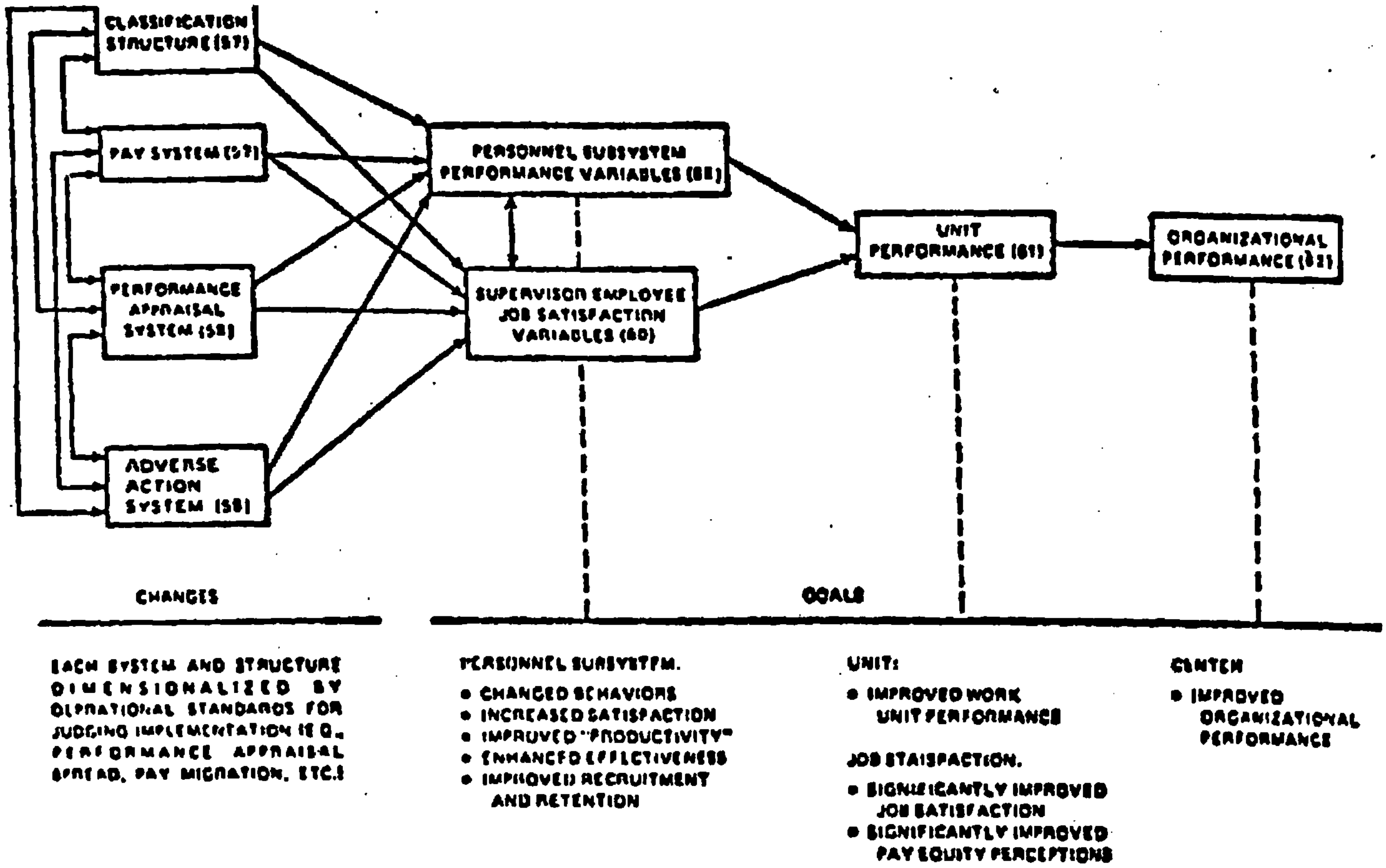


FIGURE 2. General Evaluation Schematic for Demonstration Project. The relationships between implementation of the planned changes and variables to be evauated are shown. Numbers in parentheses refer to correspondi.g pages in this proposal for further discussion.

Training

Three groups will be trained during the first year of project implementation: (1) supervisors of demonstration employees, (2) demonstration employees, and (3) personnel professionals and other administrative staff. Included in training for each of these groups will be information on the new system and how it works, and on employee and supervisor rights and responsibilities under this system. In addition, instruction and practice in objective-setting skills will prepare supervisors and employees for the Performance by Objectives process. Training for new supervisors and employees will be given throughout the 5 years of the project.

Evaluation Plan

In order to assess project outcomes and to evaluate the feasibility of applications to other federal organizations, a comprehensive and methodologically rigorous evaluation model is being developed. Figure 2 summarizes the major categories of variable involved and specifies a set of relationships that will be monitored and evaluated. The evaluation effort will include (1) pre-implementation criteria-setting and baseline data collection, (2) multidimensional performance measurements and trend evaluations at specified stated of the demonstration, and (3) a summative-phase comprehensive assessment of the project's overall impact on a set of outcome measures.

In addition to the above-mentioned measures and data, there will be an ongoing monitoring of existing records and reports on the laboratories. Unobtrusive measures will be kept on such basic considerations as the profile of the scientific and engineering work force of the laboratories, including EEO profiles to enable measurement of EEO impact as defined in the Uniform Guidelines on Employee Selection Procedures.

When methodologically justifiable, control group data will be obtained from other Navy laboratories not involved in the project.

Longitudinal measures, beginning with pre-implementation data, will be collected from the affected Centers in an effort to track impacts.

The evaluation staff will be drawn from internal and external sources. Qualified laboratory staff members will work with members of the faculty of the School of Public Administration, University of Southern California, on the design and execution of the evaluation package.

Costs

Efforts will be made to obtain congressional funding for this demonstration project. If congressional funding is not available, the costs associated with the project will be borne by the Department of the Navy and the two participating Centers, with funding provided out of normal activity training and administrative overhead funds. The total cost for the 5-year project is estimated to be $2,700,000 (in fiscal year 1978 dollars). It should be noted that a significant part of this cost would otherwise be incurred in implementing the provisions of the Civil Service Reform Act of 1978.

Authorities and Waivers of Law and Regulation Required

Specific authorities are needed by the participating Centers to establish and implement new merit pay control techniques not currently in the law. In addition, authority is needed to waive or modify certain sections of Title 5 in order to give project participants the necessary classification authority, merit pay flexibility, and other authorities to accomplish the demonstration project.

Anticipated Benefits of Project

The project is expected to demonstrate that a management-centered personnel administration process will lead to more efficient and effective use of the resources of the participating Centers. In addition, by providing a means of real-world testing for models of improved and simplified classification and performance evaluation systems, the project will have results that can be applied throughout the Federal service. Some examples of anticipated effects caused by the changes and corresponding measures for evaluating these effects are depicted in Table 1.

TABLE 1. Some Examples of Anticipated Effects Caused by the Planned Changes, With Measures for Evaluating These Effects.

Change	Anticipated effects	Evaluation measures
Classification and pay........	Increased recruitment success	Cost per recruit, recruit quality and quantity
	Flexibility of workload assignment	Time, cost of reassignments and transfers
	Increased personnel subsystem "productivity"	OPM productivity measurement approach
Performance appraisal..	Correlation of pay and performance	Perceived equity
	Increased employee commitment	Satisfaction and commitment instruments ("A" Survey)
	Decreased turnover of "desirable" employees	Turnover rate of critical employees
	Increased turnover of low performers	Turnover rate
	Increased organizational effectiveness	Peer, sponsor, and user evaluations; cost to conduct business
Retention..	Retention of high performers	Retention rates
Adverse action.....	Improved behavior of problem employees	Number of suspended penalties affected as opposed to those not affected

TABLE 2. All Technical Professionals (GS-5 through -15) and All Other GS-13 through -15 Employees Included in the Initial Increment of the Demonstration Project.

Type of occupation		Approximate number of eligible personnel by participating activity	
Series	Title	NOSC	NWC
28	Environmental protection specialist.......	...	2
132	Intelligence specialist..................	5	0
150	Geographer...............................	...	1
180	Engineering psychologist.................	19	4
330	Digital computer systems administrator....	1	...
334	Computer specialist......................	96	...
340	Program manager..........................	4	3
345	Program analyst..........................	12	2
391	Communication management specialist.......	6	...
393	Communication specialist..................	14	...
401	Biological scientist......................	11	1
403	Microbiologist............................	1	...
408	Ecologist.................................	1	...
410	Zoologist.................................	1	...
413	Physiologist..............................	2	...
701	Veterinary scientist......................	1	...
801	General engineer..........................	49	151
806	Materials engineer........................	7	7
808	Architect.................................	...	7
810	Civil engineer/structural engineer........	1	11
830	Mechanical engineer.......................	98	193
850	Electrical engineer.......................	4	6
855	Electronics engineer......................	664	454
861	Aerospace engineer........................	...	102
893	Chemical engineer.........................	1	16
896	Industrial engineer.......................	2	1
1301	Physical scientist........................	10	7
1306	Health physicist..........................	1	...
1310	Physicist.................................	222	200
1313	Geophysicist..............................	1	...
1320	Chemist...................................	12	59
1321	Metallurgist..............................	...	4
1350	Geologist.................................	...	2
1360	Oceanographer.............................	20	...
1515	Operations research analyst...............	57	63
1520	Mathematician.............................	76	93
1529	Mathematical statistician.................	2	3
1550	Computer scientist........................	7	13
All Other	GS-13 through -15 employees...............	32	61
	Total.....................................	1,430	1,466

APPENDIX G

EXAMPLE OF A VERTICALLY INTEGRATED PROGRAM

THE U.S. DEPARTMENT OF DEFENSE PROGRAM FOR DEVELOPMENT OF VERY HIGH SPEED INTEGRATED CIRCUITS

Example of a Vertically Integrated Program

THE U.S. DEPARTMENT OF DEFENSE PROGRAM FOR DEVELOPMENT OF VERY HIGH SPEED INTEGRATED CIRCUITS

I. Introduction

This paper describes a new conceptual approach to the management of major DoD technology initiatives which is based on "vertical integration." Such vertical integration includes:

- Centralized management and coordination of the total tri-Service program with fenced funding to ensure accountability.
- The inclusion under one industrial organization of all aspects of a technology's development and transition into military systems (e.g., processes, design, materials, etc.).
- Continuity of the industrial team/s from early technology development through transition to system applications.
- Early consideration of multiple system demands on the technology to define not only the individual technological thrusts but also the necessary interaction of diverse technologies (e.g., processes, architecture).

The VHSIC program is managed using this concept. It can be generalized for application to other technology base programs. This paper presents the DoD VHSIC program as an example of such a technology base management concept.

II. VHSIC Program

The very high speed integrated circuit (VHSIC) development area covers technologies supporting design and architecture methods for laying out chips with up to 100,000 active elements; providing the advances in lithography and processing necessary for 1.25μ to submicron linewidths; and developing philosophies of VHSIC design, architecture, software, and testing (DAST). The VHSIC program is a vertically integrated, tri-Service effort with FY 81 funding of $40M. DARPA also funds related technology and research (VLSI) ($21.6M). The program has demonstrated the processing and lithography capability for 1.25μ features for silicon devices.

The VHSIC program is motivated by the DoD's desire to:

- Maintain a qualitative lead in key technologies over our principal adversaries in furtherance of the U.S. military philosophy of countering numerical superiority through qualitative superiority in arms (force multipliers), and
- To provide affordable and reliable military systems which incorporate <u>transparent complexity</u>.

After a decade of low investment in IC technology and a trend toward a total dependence on commercial product lines, the DoD initiated this program to focus industry R&D on integrated signal processing systems in areas of high military utility. The desired end goal is a line of devices which are the signal processing counterpart* to commercial microprocessors and which incorporate order of magnitude improvements in performance, availability, usability, and affordability. Key areas of VHSIC military utility are:

- Autonomous, adaptive satellite sensor and RPV sensor processing (IR, ESM, and radar)
- Anti-jam communications and radar systems with very wide instantaneous bandwidths
- Survivable, intelligent distributed processing
- Adaptive missile guidance with improved accuracy, recognition capability, and ECCM
- Implement in real-time advanced acoustic array processing and rapid correlation and screening of multiarray data
- Adaptive navigation and guidance.

VHSIC technology offers greatly improved capabilities in self-test and repair, and offers simplified operation (transparent complexity). Such devices will enable a wide range of revolutionary military capabilities through their 100-fold increase in signal processing speed, greatly reduced cost per function, and lower size, weight, and power.

The management philosophy of the VHSIC program provides a strong tie between defined military needs and the evolution of the complex VHSIC signal processing systems. The VHSIC program has four phases. Phase 0 was the program definition stage. Phase 0 was guided by architectual studies of Service-identified, high priority systems (see Figure 1). An architectural approach was sought which provides a minimum chip set to fulfill signal processing requirements between systems of diverse generic types. Phase 0 provided more detailed and complete information on architecture, IC technology approaches, and other important aspects prior to making major program decisions. It set the stage for the vertical integration of Phases I and II.

---

* Signal processing may be clearly distinguished from data processing based upon the different operations performed by each. Signal processing operations include correlation, convolution, transformation, nonlinear filtering, ambiguity function calculation, coherence function calculation, etc. In general, signal processing is robust and tolerant of occasional errors in the sense that the accuracy of the output may be degraded but not eliminated. On the other hand, data processing consists of operations such as branching, jumps, decisions, listing, general logic, etc. Data processing is generally intolerant of errors. For example, a signal error at a conditional branch point can collapse the whole program because data begins to be read as instructions.

Phase I has two parallel efforts. The first part seeks to accomplish an interim goal of developing VHSICs with 1.25 feature sizes. This interim goal will provide near-term circuits which will be applied to specific systems. The second effort addresses the technology problems associated with crossing the one micron barrier. Lithography, dry processing, etc. are areas to be emphasized. Phase I is a vertically integrated effort, with systems design/architecture/software and IC fabrication and production closely combined into a single synergistic program. A pilot production capability for 1.25 VHSICs is major goal. Phase I is planned to be 2 1/2 to 3 year effort. Figure 2 shows the Phase I efforts.

Phase II also has parallel efforts. The first part is to build system demonstrations using ICs developed with 1.25 minimum feature sizes. These system demonstrations are being designed to expedite the introduction of advanced ICs into future military systems; to provide tangible evidence of the value of the IC development to the DoD system community; to serve as a mid-point validation of the design and fabrication technology; and to realize a near term return on the DoD investment. The second part of Phase II will extend the state-of-the-art of IC fabrication to submicron feature sizes (nominally 0.5 to 0.8 microns). A pilot production capability for submicron ICs is the major goal of this part of Phase II. Additionally, this part is essential to meet the more advanced projected systems needs. As in Phase I, Phase II is also a vertically integrated program, combining design/architecture; software and IC fabrication and production into a single progam.

Phase III is a six year progam run in parallel to Phase I and II consisting of technology efforts to support and supplement Phase I and II. Phase III is intended to provide new and/or alternative directions not specifically included in the other phases. In contrast to Phase I and II which are large vertically integrated program, Phase III consists of shorter programs, with more limited scope, focusing on key technologies, equipment, or tools.

The overall VHSIC management structure emphasizes close coordination among the various Service efforts to provide feedback and a high degree of cooperative learning and development. The net effect of this tie among system designers and technologists from diverse areas (e.g., ASW, radar, communication) is a closer integration of the total VHSIC effort.

To insure that the resources are properly allocated a new program element was established with "fenced" funding, controlled by the VHSIC programs manager.

In summary, the vertical integration of the VHSIC is as described below:

1. Top down management and coordination of the VHSIC program by USDR&E with "fenced" funding and a clear audit trail.

   Result: This structure helps to meld the diverse needs of the Services into a common technology base, to avoid duplicative efforts and to focus the available funds on the highest payoff/opportunities.

2. The inclusion of system top level requirements definition, architecture development, DAST and IC processing development within each Phase I and Phase II contract.

   Result: Such an approach fosters a multidiscipline technology development with a direct system requirements to technology to system transition linkage. Recognition of the total system as the driving force for VHSIC chip design, and acceptance of the fact that chip commonality among systems of a generic type and between systems of diverse generic types must be maximized, will result in fundamental changes in chip level emphasis. The end result is the integration of all these technical factors into a systematic VHSIC chip capability which is strongly coupled vertically and horizontally with signal processing systems specification and design.

3. Maintaining continuity of the Phase I and Phase II contractors/contractor teams from the requirements definition stage through technology development through transition to engineering development within military systems.

   Result: This continuity will develop the total industry capability necessary for production of the VHSIC devices and early demonstrations of the costs and risks associated with their applications.

4. Early and continuing input of a wide range of system top level requirements (see Figure 1) into the technology development effort encouraging an optimal balance between custom design for specific applications and use of standard building blocks.

   Result: This creates an environment within which the signal processing interests and expertise throughout all three Services can creatively and productively interact on a continuing basis. This interaction will lead to integrated VHSIC systems with high value to a range of military signal processing applications. The result will be very early transition into military systems.

FIGURE 1

VHSIC SYSTEM CANDIDATES

ARMY

Multi-Mode Fire-and-Forget Missile
Battlefield Information Distribution System
EW Weapons Targeting System
Target Acquisition Fire Control System

NAVY

Acoustic Signal Processor
A/J Communication Modems
Surveillance Radar Signal Processor
Tactical Radar Signal Processor
ESM Signal Sorter
Imaging System Signal Processor
General Purpose Computer

AIR FORCE

Programmable Radar Signal Processor
Programmable Communications Processor
E-3A Universal Signal Processor
Advanced Air-to-Air Missile
Autonomous Cruise Missile Guidance
Advanced Power Management System
General Purpose Computer
Advanced Onboard Signal Processor

FIGURE 2

VHSIC PHASE ONE CONTRACTORS

CONTRACTOR	FEATURES	BRASSBOARD
TEXAS INSTRUMENTS (Army)	• Provides Essential M^2F^2 BB • Variant Bipolar Tech Coverage • Programmable Chip Set Arch. Approach • Pilot Line Already Operating	Multimode Fire and Forget Missile
HUGHES (Army)	• CMOS/SOS Technology • Hybrid/Custom Design Architectural Approach	Battlefield Infomation Distribution System
TRW (Navy)	• Bulk CMOS and Bipolar Coverage • Single Chip Set Architectural Approach	EW Signal Processor
IBM (Navy)	• Provides Essential Acoustic BB • NMOS Technology Coverage • Customized Macro-Cell Arch. Approach • Outstanding Knowledge of Computer Software	Acoustic Signal Processor
HONEYWELL (Air Force)	• Bipolar Technology Coverage • Custom Design Architectural Approach	Electro-Optical Signal Processor
WESTINGHOUSE (Air Force)	• Provides Essential Radar BB (Tactical) • Alternate Bulk CMOS Coverage • Alternative Single Chip Set Approach	Advanced Tactical Fighter Radar Processor

APPENDIX H

RECOMMENDATIONS FROM THE DoD LABORATORY MANAGEMENT TASK FORCE

RECOMMENDATIONS FROM THE DOD LABORATORY MANAGEMENT TASK FORCE (JULY 1980)

PERSONNEL & MANPOWER

ISSUE:
- FREQUENTLY CHANGING MANPOWER CEILINGS

PROBLEM:
- SIZE, FREQUENCY AND SCHEDULING OF CHANGES

IMPACTS:
- MANPOWER TURBULENCE (SIZE AND MIX)
- INEFFICIENT WORKLOAD PLANNING & EXECUTION
- ADMINISTRATIVE BURDEN

ACTIONS:
- CONTINUE EFFORT TO STABILIZE DoD CEILING
- DETERMINE THE IMPLICATIONS OF THE PENDING FULL TIME EQUIVALENT (FTE) PROCEDURES
- REMAIN ALERT TO POSSIBLE CONGRESSIONAL EXEMPTIONS TO CEILINGS FOR INDUSTRIAL FUNDED ACTIVITIES

RECOMMENDATIONS:
- SECDEF CONTINUE TO SEEK STABILIZED CEILING
- LMTF EXAMINE FTE IMPACTS ON LABORATORIES
- OSD SUPPORT REMOVAL OF CEILINGS FOR LABORATORIES FROM INDUSTRIAL FUNDED LABORATORIES
- SECDEF USE DISCRETIONARY AUTHORITY TO STABILIZE LABORATORY CEILINGS

PERSONNEL & MANPOWER

ISSUE:
- HIGH GRADE REDUCTION FOR CIVILIAN SCIENTISTS AND ENGINEERS AND ASSOCIATED LABORATORY PERSONNEL

PROBLEMS:
- SEC 811(A) OF PL95 79 (FY79 AUTHORIZATION BILL) MANDATES DRAWDOWN
- CIVIL SERVICE REFORM ACT PL95-454 SAVE GRADE PROVISION NEGATES USE OF DOWNGRADING TO MEET MANDATORY REDUCTION

IMPACTS:
- RESTRICTION DISTORTS GRADE DISTRIBUTION AND MIX
- ADVERSE EFFECTS ON CAREERS PROGRESSION, RETENTION, AND HIRING
- PREORDAINS POORER QUALITY LABORATORIES IN FUTURE

ACTIONS:
- REPEAL SEC 811(A) AS RECOMMENDED IN SEC 803 OF HR 6974 (FY81 AUTHORIZATION)
- MODIFY SEC 811(A) TO LIMIT OVERALL REDUCTION TO THAT ALREADY ACCOMPLISHED
- MODIFY PL95-454 TO ALLOW CREDIT FOR HIGH GRADE POSITIONS DOWNGRADED ALTHOUGH INCUMBENTS RECEIVE SAVE GRADE
- OBTAIN EXEMPTIONS FOR GS-13'S
- CREATE DEFENSE SCIENCE AND TECHNOLOGY (S&T) SERVICE

RECOMMENDATIONS:
- SECDEF SUPPORT REPEAL OF SEC 811(A) OF PL 95 79
- OSD WORK WITH OPM TO CREATE DEFENSE S&T SERVICE

PERSONNEL & MANPOWER

ISSUE:
- SALARY COMPETITION

PROBLEMS:
- NEW AND RECENT GRADUATES
  - SPECIAL SALARY SCHEDULES LIMITED BY 5USC5303
  - S&E GS 5/7 ENTRY LEVELS AT MAXIMUM UNDER LAW GS 9/11 LEVEL INCLUDED BUT NOT AT MAXIMUM
- EXPERIENCED (JOURNEYMEN)
  - 5USC5333 REQUIRES APPOINTMENTS AT STEP 1
  - GS 11/18 HIRING ABOVE STEP 1 REQUIRES AGENCY HEAD AND OPM APPROVAL

IMPACTS:
- NEW AND RECENT GRADUATES–EXISTING RATES INSUFFICIENT TO ATTRACT AND RETAIN MOST S&E SPECIALITIES
- JOURNEYMEN–PROCESS NOT TIMELY (RESULTS IN ESCAPE OF CANDIDATE)

ACTIONS:
- PURSUE ACTION WITH OPM TO ENSURE REPEAL OF SALARY SCALE LIMIT IN 5USC5303
- EXPLOIT RECENTLY DELEGATED AUTHORITY UNDER OPM BULLETIN 300 52 "ADVANCED IN HIRING RATES BASED ON SUPERIOR QUALIFICATIONS"
- RAISE GS 9/11 S&E TO COMPETITIVE LEVELS

RECOMMENDATION:
- OSD SUPPORT BOTH OF THESE ACTIONS AND WORK TO ADJUST OVERALL S&E PAY SCALE TO PROVIDE MARKET COMPETITION

PERSONNEL & MANPOWER

ISSUE:
- TRAVEL AND RECOMMENDATION LIMITS FOR MISSION RELATED WORK

PROBLEMS:
- ADMINISTRATIVE TRAVEL RESTRICTED SINCE FY76 (PL94 157)
- FY80 CONTINUING RESOLUTION (PL95 25) MANDATES $500M FEDERAL TRAVEL CUT
- DoD CUT ($375M) NOW AFFECTS MISSION, TECHNICAL TRAVEL AND TRANSPORTATION OF THINGS (OBJECT CLASS 22) AS WELL AS ADMINISTRATIVE
- INHIBITS PERSONNEL TRANSFERS, EMPLOYMENT, LIAISON, TRAINING, AND SCIENTIFIC EXCHANGE

IMPACTS:
- RESTRICTIONS DIRECTLY IMPACT PROGRAM CONDUCT AND ACCOMPLISHMENT
- FORCES INEFFICIENT USE OF FUNDS AND POSSIBLE BORDER LINE PRACTICES

ACTIONS:
- URGE CONGRESSIONAL REPEAL OF SEC 112 (PL96 86)

RECOMMENDATION:
- DoD SUPPORT ACTIONS TO REDUCE MISSION IMPACTS

PERSONNEL & MANPOWER

ISSUE:
- INSPECTIONS AND AUDITS

PROBLEMS:
- REPETITIVE, OVERLAPPING, RANDOMLY SCHEDULED INSPECTIONS AND AUDITS DIVERT TECHNICAL MANPOWER FROM PRIMARY MISSION RELATED TASKS
- SHORT NOTICE PRECLUDES ADEQUATE PREPARATION OF RESPONSES

IMPACTS:
- DELAY IN PROGRAMS
- INTERRUPTION OF TECHNICAL ACTIVITIES
- DIFFICULTY IN PROVIDING ADEQUATE RESPONSES TO LEGITIMATE CONCERNS OF THE INSPECTIONS AND AUDITS ON SHORT NOTICE
- COSTLY, INEFFICIENT, AND SEEMINGLY EXCESSIVE

ACTIONS:
- DEVELOP UNDERSTANDING WITH INVESTIGATING AND AUDITING BODIES CONCERNING SCHEDULES, DEMAND ON PEOPLE AND FACILITIES, AND PLANNED FREQUENCY AND DURATION OF VISITS

RECOMMENDATIONS:
- OSD TAKE LEAD IN DEVELOPING UNDERSTANDING WITH ITS OWN AND EXTERNAL INVESTIGATING AGENCIES
- SERVICES DEAL WITH THE PROBLEMS ARISING FROM INTERNAL AUDITS AND INVESTIGATIONS

FACILITIES

ISSUE:
- INADEQUATE MODERNIZATION OF LABORATORY FACILITIES

PROBLEMS:
- MANY FACILITIES ARE SUBSTANDARD/INADEQUATE/OBSOLETE/ENERGY INEFFICIENT
- ADVANCING TECHNOLOGY AND NEW PROGRAMS REQUIRE APPROPRIATE FACILITIES

IMPACTS:
- INHIBITS WORK PRODUCTIVITY AND SLOWS DEVELOPMENTS
- DOES NOT ATTRACT AND SUPPORT HIGHEST QUALITY SCIENTIFIC AND TECHNICAL PERSONNEL
- REDUCES ABILITY TO PROVIDE PROGRAM AND LIFE CYCLE SUPPORT
- FACILITY CONSTRUCTION OFTEN LAGS R&D PROGRAM REQUIREMENTS

ACTIONS:
- ENSURE SIGNIFICANT MONETARY INVESTMENT IN R&D FACILITIES FOR EACH SERVICE OVER NEXT 10 YEARS

RECOMMENDATIONS:
- SECDEF AND DoD ESTABLISH A LABORATORY FACILITIES MODERNIZATION POLICY TO INSURE REPLACEMENT OF FACILITIES IN A TIMELY MANNER SPECIFICALLY TAILORED TO THE BUSINESS VENTURE CHARACTERISTICS OF LAB SYSTEM (AS A MINIMUM, A FACILITIES MODERNIZATION PROGRAM FOR EACH SERVICE SHOULD BE ABOUT $70M EACH YEAR FOR THE NEXT TEN YEARS)
- OSD SELL THIS POLICY TO THE CONGRESS AND DoD AGGRESSIVELY MONITOR ITS IMPLEMENTATION
- IN ADDITION, DoD SHOULD SUPPORT CONSTRUCTION OF NEW FACILITIES ON A CASE BY CASE BASIS

PROCUREMENT AND ACQUISITION

ISSUE:
- DETERMINATION AND FINDINGS (D&F) LIMIT AND PROCESS

PROBLEMS:
- D&F $100K LIMIT TOO LOW (D&F HAS 1962 BASE) AND APPROVAL PROCESS TOO LENGTHY
- USED AS PROGRAM APPROVAL DOCUMENT (NOT LEGISLATIVELY INTENDED)

IMPACT:
- EXTENSIVE REVIEWS AT MULTIPLE LEVELS SIGNIFICANTLY INCREASE TIME REQUIRED FOR CONTRACT AWARD

ACTIONS:
- LEGISLATIVE CHANGES TO INCREASE THRESHOLD FROM $100K TO $1M (52% DECREASE IN ADMINISTRATIVE BURDEN AND YET ONLY 2% OF TOTAL DOLLARS CURRENTLY UNDER D&F'S WOULD NO LONGER REQUIRE SECRETARIAL APPROVAL)
- INCREASE THE USE OF CLASS D&F'S
- STREAMLINE PROCESS

RECOMMENDATIONS:
- OSD CONTINUE TO SEEK LEGISLATIVE CHANGES
- DoD INTERIM MEASURE USE CLASS D&F'S WHENEVER POSSIBLE
- DoD REDUCE INSTITUTIONAL REVIEWS TO ONE PER LEVEL

EQUIPMENT

ISSUE:
- INSUFFICIENT MODERNIZATION AND ACQUISITION OF LABORATORY EQUIPMENT

PROBLEMS:
- MUCH LABORATORY EQUIPMENT IS SUBSTANDARD/OBSOLETE
- ADVANCING TECHNOLOGY REQUIRES NEW LABORATORY EQUIPMENT
- GENERAL PURPOSE EQUIPMENT PURCHASES SEVERELY LIMITED
- NO EQUIPMENT RESERVE FUND

IMPACTS:
- INHIBITS WORK PERFORMANCE
- DOES NOT ATTRACT AND SUPPORT HIGH QUALITY SCIENTIFIC AND TECHNICAL PERSONNEL
- COSTLY TO MAINTAIN OLD EQUIPMENT AND WASTES MANPOWER

ACTIONS:
- ESTABLISH CHARGE SYSTEM FOR EQUIPMENT DEPRECIATION
- INCREASE 6.5 NOTE LINE BUDGET FOR EQUIPMENT
- ENSURE SIGNIFICANT MONETARY INVESTMENT IN EQUIPMENT

RECOMMENDATIONS:
- DoD MODIFY EXISTING REGULATIONS (E.G., DoDD 7410.4) TO PERMIT DEPRECIATION CHARGES AT APPROPRIATE LABORATORIES
- SECDEF AND DoD ESTABLISH A LABORATORY EQUIPMENT MODERNIZATION POLICY TO INSURE THAT GENERAL PURPOSE EQUIPMENT IS REPLACED OR ACQUIRED IF NEW IN A TIMELY MANNER (WITH AVERAGE LIFE BASED ON IRS STANDARDS FOR PRIVATE ENTERPRISE)
- EACH SERVICE HAVE AN EQUIPMENT MODERNIZATION PROGRAM OF AT LEAST $25-30M EACH YEAR FOR THE NEXT TEN YEARS

PROCUREMENT AND ACQUISITION

ISSUE:
- CONTRACTING

PROBLEM:
- MANY DoD LABORATORIES ARE IMPEDED BY LACK OF DEDICATED CONTRACT SUPPORT, LIMITED IMPREST FUND AUTHORITY, LIMITED ACQUISITION AUTHORITY, AND REQUIREMENT TO FOLLOW MAJOR SYSTEM PROCUREMENT FOR NONMAJOR CONTRACTING

IMPACTS:
- UNACCEPTABLY LONG LEAD TIMES FOR PROCESSING CONTRACTS
- SERIOUS DELAYS IN RECEIPT OF SUPPLIES AND SMALL PURCHASES
- IMPREST FUND LIMIT DENIES OPERATIONAL FLEXIBILITY
- INSUFFICIENT AUTHORITY AT LABORATORY LEVEL TO PROCESS BULK OF CONTRACTUAL WORKLOAD

ACTIONS:
- CHANGE POLICIES TO PROVIDE FOR ADEQUATE CONTRACTING AUTHORITY AND SMALL PURCHASE SUPPORT WITHIN LABORATORIES
- RAISE DOLLAR VALUE OF IMPREST FUND AUTHORITY FROM $150/200 TO $300/700

RECOMMENDATIONS:
- DoD PROVIDE DEDICATED R&D CONTRACTING ACTIVITIES FOR LABS
- OSD INSTRUCT DEFENSE ACQUISITION REGULATION (DAR) COMMITTEE TO AMEND DAR IMPREST FUND THRESHOLDS
- DoD INCREASE SMALL PURCHASE FLEXIBILITY & CONTRACTING AUTHORITY

PROCUREMENT & ACQUISITION

ISSUE:
- NEEDED SPECIAL FINANCIAL MANAGEMENT SYSTEMS FOR LABORATORIES

PROBLEMS:
- INDUSTRIAL FUNDING, ALTHOUGH A GENERALLY EFFECTIVE FINANCIAL SYSTEM, DOES NOT ADEQUATELY ADDRESS BARRIERS SUCH AS:
  - RATE STABILIZATION
  - INCREMENTAL FUNDING
  - CONTINUATION OF WORK AT THE BEGINNING OF A NEW FISCAL YEAR
  - MULTIPLE FUNDED CUSTOMER ORDERS
  - FRAGMENTATION OF FUNDING
  - COMMITMENT AND OBLIGATION LEGAL LIABILITIES

IMPACTS:
- DELAYS IN WORK ASSIGNMENT
- LOSS OF PERSONNEL PRODUCTIVITY
- UNFAIR CHARGES TO CUSTOMERS
- IMPRECISE "REAL COST" ANALYSES
- MICRO FISCAL CONTROL SERVING LITTLE USEFUL PURPOSE

ACTIONS:
- ESTABLISH A "SERVICE FUND" APPROACH FOR SELECTIVE USE
- APPLY TO ALL INDUSTRIALLY FUNDED LABORATORIES (ARMY AND NAVY)

RECOMMENDATIONS:
- DoD USING NAVY SERVICE FUND STUDY AT A POINT OF DEPARTURE ESTABLISH AND IMPLEMENT THE SERVICE FUND CONCEPT

APPENDIX I

REFERENCE MATERIALS

APPENDIX I

REFERENCE MATERIALS

Investment Strategy/Tactics, Lindner, V.; U.S. Army Armament R&D Command, August 1981.

Innovation Adoption in Naval Ship Design, Leopold, R.; Naval Ship Engineering Center, May 1977.

Comments on the Transition from the Technology Base to Production, Rechtin, E.; Defense Science Board Summer Study; August 1981.

Airland Battle 2000; U.S. Army Training and Doctrine Command, 1 July 1981.

Look Forward Twenty Years; Air Force Systems Command, March 1980.

Militarily Critical Technologies List with Rationales; Undersecretary of Defense for Research and Engineering (International Policy and Technology), 15 May 1981.

Mission-Technology Correlation Assessment - An Overview; Deputy Assistant for the Secretary of Defense (Atomic Energy) (Assessment), 20 March 1981.

Report of the DoD Laboratory Management Task Force; Under Secretary of Defense for Research and Engineering (Research and Advanced Technology), July 1980.

Report of the Defense Science Board Task Force on Technology Base Strategy; Director Defense Research and Engineering, October 1976.

Tactical Airpower in Europe: Airing the European View; Assistant Secretary of Defense, Program Analysis and Evaluation, 19 July 1976.

Technology Trends Colloquium; Joint Defense Research and Engineering - Intelligence Community Publication, 1 April 1978.

Report of the Ad Hoc Committee on In-House Laboratories; Army Scientific Advisory Panel (ASAP), December 1963.

Management of Federal Contract Research Center; Director Defense Research and Engineering, June 1976.

Proceedings of an AAAS Symposium on "How Much Does the Defense Department Advance Science?"; American Association for the Advancement of Science, January 1980.

Required In-House Capabilities for DoD Research, Development, Test, and Evaluation; Office of the Undersecretary of Defense for Research and Engineering, October 1980.

Ad Hoc Group on Scientific Personnel; Army Scientific Advisory Panel, April 1964.

Report of the Joint Defense Science Board/National Bureau of Standards Panel on Research and Exploratory Development; Undersecretary of Defense for Research and Engineering, July 1967.

Report of the Science Advisor's Panel on Basic Research in the Department of Defense; Office of Science and Technology Policy, June 1978.

Historical Perspectives on Long-Range Planning in the Navy; Naval Research Advisory Council Study, September 1980.

Report of the Army Science Board on Technology Planning for Future Fielded Systems; Army Science Board 1979 Summer Study, July 1980.

Report of the Defense Science Board 1975 Summer Study on Fundamental Research in Universities; Director Defense Research and Engineering, October 1976.

Man-Machine Technology in the Navy; Naval Research Advisory Council Study, December 1980.

DoD Small Business Advanced Technology Program; DESAT, 1981-82.

Ad Hoc Review of the 1974 Army Summer Study Review; Army Scientific Advisory Board, October 1975.

Report of the Army Scientific Panel Summer Study; Army Scientific Advisory Board, 1974.

Report of the Army Science Advisory Board Summer Study; Army Scientific Advisory Board, 6 Volumes, 1976.

Report of the Army/Air Force Joint Summer Study; U.S. Air Force Academy, 1976.

Project Hindsight; Office of the Director Defense Research and Engineering, October 1969.

Department of Defense Laboratory Utilization Study (Allen Study); 1975.

Technology Assessment Methodology: ICBM; The RAND Corporation, July 1980.

An Overview of Department of Defense Space Missions, Systems, and Technology; Aerospace Corporation, March 1980.

U.S./U.S.S.R. Technology Balance Assessment; Naval Research Advisory Council, January 1980.

Military Technologies in the 1980's; Army Scientific Advisory Council, July 1970.