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THE DEPARTMENT OF DEFENSE TECHNOLOGY AREA DESCRIPTION ON RESEAR--ETC(U)
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**THE DEPARTMENT OF DEFENSE
TECHNOLOGY AREA DESCRIPTION
ON
RESEARCH**



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**BY
DR. GEORGE GAMOTA
DIRECTOR FOR RESEARCH
OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ENGINEERING
(RESEARCH AND ADVANCED TECHNOLOGY)**

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The Department of Defense
Technology Area Description
on
RESEARCH

by

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Dr. George Gamota
Director for Research
Office of the Under Secretary of Defense
for Research and Engineering
(Research and Advanced Technology)

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Research

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1. PROGRAM DESCRIPTION

1.1 Overview. The DoD Research (6.1) Program provides a base of scientific knowledge for the solution of national defense problems. These may span the spectrum from well-defined military requirements for fundamental information to the generation of new scientific concepts. The interests of the Department are broad and include most fields within the physical, engineering, environmental, biological-medical, and behavioral-social sciences. Furthermore, the nature of this program is such that it is conducted by a large number of individuals dispersed throughout many organizations.

1.2 Broad Objectives of Program. The objective of the program is to provide:

- o A source of new concepts which introduce major changes in technological and operational capability.
- o Fundamental knowledge for the solution of future military problems.

These objectives provide the foundation of the DoD Research Program and have remained essentially unchanged since its initiation directly after World War II. However, while the objectives remained unchanged, between the mid 1960's and 1970's, a trend developed to orient the Research Program toward efforts for which the benefits become more quickly realizable. Emphasis on near term, safer projects was also

accompanied by a 60 percent loss in constant dollar funding. Recognizing that this pattern of supporting research is unlikely to provide the maximum options for major Defense needs and sustained technological superiority in the future, the Secretary of Defense has sought to initiate a pattern of real funding growth and an emphasis on higher payoff, longer term research.

The Defense Research Program is funded under two distinct Program Elements: In-house Laboratory Independent Research Sciences (ILIR) and Defense Research Sciences (DRS).

1.2.1 In-house Laboratory Independent Research (ILIR).

Representing about eight percent of Defense research, this program provides Directors of DoD Laboratories a means of stimulating innovative research and a means of strengthening competence within the in-house laboratory research community. It also is instrumental in accelerating the transfer of promising research into exploratory development. Funds are usually allocated directly by the Assistant Secretary of the Military Department for Research and Development and are not subject to reallocation by intervening echelons.

1.2.2. Defense Research Sciences. Approximately 92 percent of research is funded under the Defense Research Sciences Program Elements. The objective of this program is to take maximum advantage of

the unique capabilities of each of the various performers of research: academia, in-house laboratories, industrial laboratories, and nonprofit research institutions. In research our goal is to seek and obtain the best minds in science and engineering to work on future DoD problems.

1.3 Program Management. The oversight of the Research Program is the responsibility of the Director for Research within the Office of the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology). The responsibilities of the Director for Research are: to see that the Secretary of Defense's policy with regard to Defense research is implemented; to provide guidance for and to review the research programs of the Military Departments; to ensure support of programs which may have broader significance than that perceived by the individual Military Departments, but which are of future significance to DoD as a whole; and to serve as a focal point and coordinator for the DoD's Research program inside and outside the Department. The management of the DRS programs is carried out by the three Military Departments in the following manner:

- o Army - The Directorate of Army Research in the Office of the Deputy Chief of Staff for Research, Development and Acquisition has financial cognizance of research funding for work directed by the Army Materiel Development and Readiness Command (DARCOM), the Office of the Chief of Engineers, the Office of the Surgeon General, and by the Office of the Deputy Chief of Staff, Personnel. The major portion of the Army's research effort which is managed by DARCOM is block funded to the Army

laboratories. The principal objective of block funding is to place responsibility for formulation and execution of the Research Program in the hands of competent laboratory directors. Each block funded project typically corresponds to the operational function of a particular laboratory and is not categorized according to scientific disciplines. However, the largest block is for the Army Research Office (ARO), whose program is distributed along traditional scientific disciplines. ARO's role in Army research has changed significantly in the last few years as a consequence of increased funding, and its assumption of overview responsibility for the total DARCOM Defense Research Sciences program.

o Navy - The Navy research activities are the largest of the three Services and cover the widest spectrum of scientific research. The Office of Naval Research (ONR), which is under the Chief of Naval Research (CNR), is the only research office which was created by Congress and which reports directly to the Assistant Secretary of its Service. The Naval Research Laboratory (NRL), which also reports to the CNR, is the Navy's corporate research laboratory, and has the largest research effort of any DoD in-house laboratory. Of the total Navy research budget (DRS & ILIR), approximately 20 per cent goes to NRL, 60 percent goes to ONR for contracts, and the remaining 20 percent is distributed among the other Navy laboratories and Systems Commands. ONR also has financial cognizance over most of the research funding and review responsibility for NAVMAT laboratories. ONR's 6.1 program is divided into eight

broad scientific divisions which are further subdivided into fourteen subelements which track scientific disciplines rather closely. By far the largest subelement (which is also a division) is oceanography, a science supported in DoD only by the Navy.

- o Air Force - The Air Force has the least complex management structure for research activities. The Air Force Office of Scientific Research (AFOSR), which is under the Air Force Systems Command (AFSC), has the financial and management cognizance over all of the DRS-funded research efforts in the Air Force. The in-house work is distributed among all laboratories with the goal that, in the aggregate, they have at least seven percent of their technical manpower in research.

1.4 Research Opportunities. The potential for research causing significant changes in our military capability is great. The following are a few of the possibilities:

- o New techniques for the suppression of acoustic or electromagnetic signatures could make it possible to make tanks, helicopters, sea vehicles, aircraft, etc. acoustically or electromagnetically invisible, or change in appearance - an electronic chameleon!

- o There may be technologies that could make communications less vulnerable and easier to control. Imagine being able to communicate through the earth by the use of man-made neutrinos! Consider also the possibility of "piggy back" riding coded messages on the auroral

stream. These large electron currents could not only be "carriers" but also act as amplifiers of signals.

- o Consider the effect of being able not only to detect, but to recognize target features at considerable distances through the atmosphere though obscured by fog, smoke or dust. The ability to do this would materially reduce enemy "first strike" capability.

- o Imagine the savings in manpower and materials cost if we could understand surface phenomena sufficiently to eliminate corrosion and degradation of structural materials. This is particularly important for large bore guns and operations in the marine environment.

- o Advances in electronics and optics may duplicate or surpass human capabilities to analyze data, such as pattern recognition. Use of these techniques may allow for many more "on board" decisions to be carried out in projectiles and missiles.

- o Advanced weaponry using photon or charged particle "projectiles" will travel at the speed of light if current limitations to their generation and propagation are understood.

- o What if we can harness and store the energy contained in the atomic to molecular transition of hydrogen -- Imagine 50 times more energy output than HMX, today's most powerful explosive.

In short, all of these have to be considered possible products of our research program and pursued until successful results are achieved or fundamental limits discovered. All of the above represent some of the goals toward which our research is directed. To what extent these specific objectives are achieved will only be determined by the passage of time. As has often proved to be the case in the past, the greatest surprises are yet before us and our best investment is people - top researchers in their fields. For example, who would have imagined the implications of stimulated emission of radiation on military capability before the laser was conceived?

1.5 Approach to Research Objectives - Research objectives are ultimately related to military needs which are documented in various forms within each of the Military Departments. Examples include:

- o The Air Force Research Planning Guide which is revised on a biennial basis by the AFSC

- o A classified document entitled "Science and Technology Objectives" published separately by the Army and Navy.

A representative list of how research opportunities are developed includes:

- o Unsolicited research proposals to the Military Departments (by far these proposals identify the largest number of new technological options).

- o Scientific liaison with other government Departments and Agencies within subfields of science and technology

- o Professional surveillance through meetings, journal publications, and informal scientific contact

- o Scientific advisory panels

- o "Top down" requirements defined by OSD and intermediate Headquarters

- o Research innovations or breakthroughs

- o Intelligence information

1.6 Fiscal Summary - Tables I and II summarize the DoD's funding for research by Military Departments and Agencies for FY 1978 through FY 1980. Between FY 79 and FY 80 the real growth approximates 10% for the Services' programs and 36% for DARPA. The Navy's funding is the largest and is growing at approximately the same rate as the other Military Departments. The total budget requests, including the Defense Agencies, for FY 1980 is \$573.3 million, representing an increase of 20 percent (real growth of 13 percent) over FY 1979.

1.7 Technical Program Description The Research program is most easily described in terms of scientific disciplines (Table III). Forty-seven percent of the program is concerned with the physical sciences (physics, chemistry, electronics, and materials). The military operating environment (oceanography, atmospheric, and terrestrial sciences) is the second largest block, absorbing about 18 percent of the funds. Engineering sciences (mechanical and energy conversion, aeronautical sciences) and the biological and medical sciences represent approximately 15 and 10 percent of the Research program funding, respectively. Mathematics and Information sciences represent another 8 percent and behavioral and social sciences 4 percent.

o Army - The Army DRS is formally distributed among 33 projects, each representing a laboratory (20 DARCOM, 8 Medical, 4 Corps of Engineers, and the Army Research Institute for Behavioral and Social Sciences). The Army Research Office, as noted earlier, is one of the 20 DARCOM projects and is organized by scientific discipline. The remaining laboratory projects reflect mission areas, for example,

- Research in Ballistics (Ballistics Research Laboratory, Aberdeen, MD)
- Large Caliber Armaments (Larger Caliber Weapons Systems Laboratory, Dover, N.J.)

- Night Vision and Electro-optics (Night Vision Laboratory, Ft. Belvoir, VA)

- o Navy - The Office of Naval Research contract research budget accounts for approximately 65 percent of the Navy's DRS budget and the Naval Research Laboratory accounts for 23 percent. The balance (12 percent) is distributed principally between NAVAIR, NAVSEA and NAVMED; smaller amounts are allocated to NORDA, NAVELEX, and NAVFAC.

- o Air Force - The AFOSR is organized by scientific discipline and is responsible for the entire Air Force Defense Research Sciences program. The eleven Air Force Laboratories that perform research also assist the AFOSR in contracting and monitoring research with industry and universities.

1.8 Accomplishments

1.8.1 Scientific Accomplishments - The following list is representative of scientific accomplishments that have developed within the past year:

- o New Electrostrictive Materials. New materials have been discovered which generate 10 micron displacement with 200 volts applied, compared to angstrom displacement for presently used PZT materials. These new materials, which consist of multilayers and honeycomb structures of high permittivity barium titanate, and solid solutions of lead titanate

and lead-magnesium niobate, have been found to improve the figure of merit for adaptive optic mirrors by as much as a factor of 25. Using these materials, significant deformations of optical mirrors appear possible with low voltage, lightweight reliable solid state sources. Corresponding improvements in adaptive optic systems for high energy laser beam weapons, satellite applications, and ground-based systems can be anticipated.

o Reduced Ion Doppler effect. Radiation pressure cooling of ions confined in electromagnetic traps has been demonstrated. The ions can be stored for as long as one day, and through interaction with radiation have had their translational temperatures reduced. It is expected that further cooling will provide a basis for atomic frequency standards with accuracies in the range of parts in 10^{15} . Possible applications include ultraprecise navigation and increasing accuracy of strategic systems.

o Polymer semiconductor junctions. Polymer semiconductors have been made through chemical doping of the flexible conducting class of polymers based on polyacetylene $(CH)_x$. Both n and p type polymer semiconductors have been formed, and p-n junctions obtained when n and p type polymer strips are pressed together. The results indicate that a variety of semiconductor devices may be possible using cheap and widely available polymer materials.

o Acoustic propagation in ocean crust. Prediction of propagation of low frequency acoustic signals through the ocean floor depends on the structure of the ocean crust. A direct relationship has been found between the age of the ocean crust, ocean depth, configuration of magnetic anomalies, and acoustic layering of the crust. This is an important step toward understanding the general distribution of properties governing acoustic propagation in the crust, in designing surveys for detailed measurement, and for eventual operational use of crustally propagated low frequencies in ASW.

o Universal Blood Donor. The feasibility has been demonstrated of preparing a universal blood donor type through enzyme modification of the red blood cell membrane. The combination of freeze preservation of blood (also developed by DoD) through established techniques with the production of a universal blood donor type would greatly improve present capabilities for storage and utilization of blood. The correspondingly increased efficiency and improved cost effectiveness of blood banking operations holds promise of great benefit to the management of casualties, particularly in a radiological war.

o High Frequency semiconductor layers. Thin film semiconductor layers may be grown on substrates using molecular beam epitaxy (MBE) techniques. A significant improvement in the properties of Gallium Arsenide (GaAs) films has been observed when the films are grown in the presence of a 10^{-6} Torr hydrogen atmosphere. Silicon doped GaAs epitaxial layers have been grown in a hydrogen atmosphere using

MBE techniques. These films have been found to have both a higher carrier mobility and a higher donor concentration than films grown under standard atmospheres. This result will influence the quality and performance of low noise field effect transistors and very high frequency integrated circuits.

- o Superior Aluminum Alloys. Research into the refining of metals by fractional solidification has led to a process of purification of semisolid alloys by compression. This results in alloys which have up to 100 percent impurity or inclusion removed (refinement of purity up to four orders of magnitude), and homogeneous high strength 7000-series aluminum alloys have been obtained with superior properties.

- o Optical Processing. A homomorphic filter which eliminates multiplicative noise is expected to have a very significant application to optical processing systems. Much of the existing noise is due to optical aberrations which show up as unwanted multiplicative terms on the information signal. The two dimensional homomorphic filter has been realized in real time by combining a half-tone screen and a nonlinear liquid crystal light valve. Pertinent applications include multidimensional real time signal and image processing with varied applications including nonlinear filtering for trajectory control and guidance, "smart" sensing, picture processing, and bandwidth compression.

o High Altitude Radio Transmission. Transmission of radio and radar signals is strongly affected, in terms of path delay, useable frequency and propagation direction, and by irregularities in electron density along the beam path. These irregularities are very large at high latitudes, and the most pronounced of these is termed "the mid-latitude trough". An extensive study of the trough characteristics by means of in-situ measurements was made by polar orbiting satellites, and its morphology and plasma irregularities are becoming well defined.

o Complex System Design. A new mathematical technique using the Lagrangian function has been developed to deal with complex systems subject to certain specified constrained conditions. Such techniques will find application in engineering design and analysis of many systems, for example aircraft engine design, structural design, and systems analysis.

1.8.2 Transition to Exploratory Development - The following are representative of accomplishments of the Research program which are presently being transitioned to Exploratory Development:

o A numerical technique resulting from basic research on transonic flow about complex configurations has been tested for a swept wing mounted on an infinite cylinder. The aircraft industry is

modifying the technique to assist with current design problems for more realistic aircraft geometries.

- o Basic measurements and calculations on the magnetic materials used in radar absorbant coatings

- o Results of studies on the use of controlled porosity iridium foils to disperse Barium Oxide at uniform and controlled rates as a thermionic emitter have been passed on to a contract program for developing better traveling wave tube cathodes.

- o Results of studies of radiation damage in and techniques for hardening charged coupled devices (CCD) have been transitioned into a program for developing CCD multiplexers to be used on a 1983 satellite where hardness at low temperature is a critical requirement.

- o Measuring eye damage from exposure to lasers has been made simple. A microsensor for measuring retinal damage in laser irradiated eyes has been developed. This new probe offers scientists and clinicians a new tool with which to study alterations in retinal potential following laser exposure such as that from new weapon systems.

- o Anomalous atmospheric refractivity, a common feature of the marine environment, causes problems in Naval operations.

A novel root-finding method has been found recently which ensures that all important waveguide modes are employed in propagation calculations. A computer program employing this novel technique has been used in an experimental low angle radar clutter program.

- o A new method has been developed to tailor polymer systems for use as propellant binders. A complicated but straight-forward series of steps transforms the polymer into a thermoplastic. The new properties which have evolved permit easier handling as well as the possibility of recycling the propellant.

- o An organic film is placed on a metallic substrate, polymerized, and then by corona poling is made into a piezoelectric polymer. This has an excellent potential for simplified fuze design as well as reduced graze sensitivity and vulnerability to radio frequency interference.

- o Undoped, N-type, P-type, and semi-insulating iron doped single crystals of indium phosphide (InP) having defect densities of $10^3 - 10^4$ defects/cm² have been grown and are being used as substrates for epitaxial film growth studies and have also been successfully ion-implanted with Si and S ions and annealed by means of a new technique employing phosphine. InP is an important material for high frequency electronic devices.

- o A new class of drift-free optical inertial sensors (ring laser gyros) have been developed on the basis of the Sagnac effect with the laser outside of the ring and optical pulse propagation transmission in a multiloop fiber.

- o A two-line atomic fluorescence method for the measurements of local temperatures within analytical flames has been developed. This technique, using trace concentrations of atoms and molecules in jet engine exhausts, can be applied to determine spatial profiles of flame temperatures in combustor design.

- o Investigation of high temperature metal-matrix composites resulted in the successful incorporation of tungsten filaments in a depleted uranium matrix using vacuum infiltration techniques. The results indicate that the technique has high potential for improving performance of kinetic energy penetrator materials.

1.8.3 Impact of Past Accomplishments - The impact of truly major research accomplishments of the past typically becomes apparent only after ten to twenty years and is often difficult to trace. As an example, the first maser (microwave amplification by stimulated emission of radiation) was provided in 1954 as a result of DoD support under the Joint Services Electronics Program. Although this device had many military applications of its own, primarily as

a sensitive receiver for navigation, surveillance, detection, and communications, it was a unique and an absolutely necessary precursor of the laser (light amplification by stimulated emission of radiation) concept. The impact of the laser on military operations has already been enormous and continues to grow. A few examples include new systems for guiding bombs, missiles, and cannon launched projectiles, and as a gyroscope for navigation and stabilization of naval vessels, aerospace vehicles, weapons platforms, and missiles.

Even some of the most abstract research results can have a major impact on military operations as demonstrated by the realization of the Kalman filter from the study of mathematics. The Kalman filter is best described as a software data processor designed to filter signal noise. Discovered under Air Force sponsorship in 1960, it is now in routine use in all navigation (position location) systems: inertial navigation, satellite navigation, radio navigation, and radar and sonar tracking systems. In uniquely military applications, it is an integral part of missile guidance systems. Other examples that have been developed within the past decade include:

- o The application of "press forging" to produce transparent armor and erosion resistant missile domes

- o Fundamental basis to establish failure criteria for metallic materials used in the design of submarine hulls and reactor containers

- o Mathematical statistical tools for naval provisioning processes used by the Polaris and F14 programs

- o Methods for lubrication of rapid firing guns at low temperatures and of precision bearings in missile guidance

- o Atomic standards fundamental to the development of the NAVSTAR Global Position Satellite system

- o Surface acoustic wave devices for defense electronics and avionics

1.9 Research Emphasis

- o New Materials and Better Characterization of Existing Materials - New techniques will be studied with the goal of producing systems with unusual electrical and magnetic properties, such as intercalated graphite and ion-implanted silicon. The determination of how structure, constitution, and defects relate to material response will provide assurance of reproducibility of processing and performance. These studies are basic to DoD interest in turbine superalloys, optical components, electronic materials, control devices, and other applications.

- o Emergent Combat Environments - Increasing emphasis will be placed on visible, near-millimeter, and infrared transmission

through the obscured atmosphere for improving surveillance and target acquisition capabilities. Other efforts will develop satellite remote sensing technique to infer subsurface oceanography, incorporate ocean environmental data into sonar performance model, and develop procedures for rapidly merging remotely sensed data with stored static data for real time updating of coastal data base. Long-range forecasts of solar and magnetospheric disturbances of prime communications links will be investigated.

- o Determination of Fundamental Physical Limits - The exploration of the limits of phenomena often provide clues to technological options. Included in this area are investigations of the limits of ultrahigh pressures; the evaluation of radio interferometric techniques for precise time and earth rotation parameters; the stability of lasers; and the possible use of the auroral streams for communication.

- o Microelectronics - Fundamental research in physics, chemistry, and materials science of ultrasubmicron electronics (20 to 500 Angstroms) will be pursued for an understanding of the regime where quantum effects, defects, and surface behavior dominate over traditional bulk properties of semiconductor electronics. Architecture and algorithms for advanced multidimensional signal processing will be explored.

- o Alien Environments - The regime of very high loading rates, such as encountered in ballistic shock and laser pulsing, will receive greater emphasis. For example, techniques will be explored to improve the predictive response of submarine structures to underwater

explosions. Research will also be undertaken to investigate ion implantation for enhancing corrosion and wear resistance of steels, problems of biodeterioration will be solved (particularly fouling and corrosion in the marine environment), and chemical processes which are responsible for toxic products and smoke in organic fuel oxidation will be examined.

- o Individual Survivability - Field studies will be done to explore possible atmospheric backgrounds that limit remote sensing of dispersed biological agents by use of laser-induced fluorescence and ranging. Investigations will examine the physiology of sleep and the effects of sleep fragmentation and/or disruption of biological rhythms as they affect the performance of military personnel. Research also will be done on stress factors related to limitations imposed by pressure conditions at depths approaching 3500 feet of sea water.

1.10 Nontechnical Characterization

- o Research Funding By Performer - Table IV indicates the funding distribution of the Military Departments. The following features are evident:

The distribution among performers for the three Military Departments combined in FY 1980 is:

o Universities, 47 percent

o In-house, 37 percent

o Industry and nonprofit, 16 percent

We also note significantly greater involvement by the Army for in-house research (57 percent as compared to 32 percent for the Navy and 21 percent for the Air Force)

o Funding Size Distribution - The Army and Navy have well defined concentrations of work units with annual funding levels between \$26 to \$50 thousand annually. The Air Force has a broader "peak" between \$26 to \$100 thousand annually. Although not reflected in this table, there has been an upward trend in the average cost per work unit, and a significant increase in numbers of projects ("cluster programs") in excess of \$150 thousand annually. In the last two years there has been an increase of over 125 percent in the number of these projects.

o Investment in Capital Equipment - The following summarizes the investment in new capital equipment by Military Department:

	FY 78	Est FY 79	Est FY 80
Army (ARO only)	5%	5%	5%
Navy	5%	5%	5%
Air Force	5%	6%	6%

2. PROGRAM ANALYSIS

2.1 Program Strengths and Weakness - The following characterize the strengths and weaknesses of the DoD Research program;

- o A definite strength is the substantial flexibility in choice of performers, namely the university community, the in-house laboratories, and the industrial and nonprofit laboratories. Furthermore, there exists reasonable turn-over among chief investigators within the academic and industrial groups.

- o The current support for long-range orientation of the Research program by OUSDRE staff, including specialists concerned with exploratory and advanced development of the program, is encouraging. This climate also needs to be reinforced within the Military Departments.

o The history for Research funding since FY 1976 and projections through FY 1980 provide an important tool for a more dynamic program, and presents an opportunity to seek a broader involvement of the national research community in DoD problems.

o The active interest and participation in the transfer of information from Research to Exploratory Development by the research community has been a healthy development over the past decade.

o The strengthening of the ARO role has tended to improve the overall total Army Research effort.

o The Navy's large investment with a single laboratory (NRL) provides substantial support to the DoD's leading research facility.

o The AFOSR management of the Air Force's Research program provides an important tool for integrating the diverse Air Force interests and fostering technology transfer. This management tool should be more fully utilized.

o A weakness of the program is the continued heavy emphasis on short-term oriented projects with inadequate support of the long term high risk, high pay-off work.

o The continued lack of adequate support for acquisition of scientific equipment reduces the chances of new breakthroughs. Measures to correct this problem should receive high priority.

o In some cases, there appears to be confusion with regard to the unique roles of the various performers as applied to Research. The academic performer is the source of revolutionary scientific concepts or provides a unique capability of performing specialized research that is unmatched in-house or within industry. The power of the in-house performer is his access to unclassified as well as classified military needs. The in-house research performer has a particular responsibility to interpret scientific innovations as a means of solving military problems. In some areas the military labs play a unique role, as, for example, in the areas of explosives and propellants research. The industry performer reduces to practice the scientific concept in the most economical way possible.

o There exists a tendency to judge the relevance of work units individually. More emphasis should be placed on standards of excellence and scientific priorities, with relevance criteria applied to broad scientific and engineering areas rather than individual tasks.

o The Army's research investment is spread over the largest number of laboratories and agencies (33). This results in a magnification of the tendency to use 6.1 funds to "fix up" the larger and "more

important" exploratory development, advanced development, and project manager problems.

- o The fragmentation of authority (direct and indirect) over the content of research programs dilutes the effort of competent managers within the Laboratories and OXR's. This gives rise to conflicting program objectives and dilutes the impact of the program.

- o There are major scientific subdisciplinary areas in which two and often all Military Departments have a longstanding interest. New and improved mechanisms for joint funding should be developed. This problem includes individual investigators who presently receive long-term and substantial support from as many as four DoD components, not counting other federal agencies. This results in wasteful paperwork which dilutes the effort of the productive researcher.

- o The Joint Services Electronics Program (JSEP) has seen major management changes in the last three years, and the number of participating schools has increased by 40 percent. However, the funding for this program has not kept pace even in terms of inflation. Above average growth with decisive management is needed to continue to attract top quality people and replace obsolete scientific equipment.

2.2 Managerial Accomplishments - The following highlight the managerial accomplishments within the Military Departments:

o Army - The Army Research Office established a Technology Transfer Office to improve the identification and transfer of ARO results to applications within Army laboratories. The major activities are the identification of new accomplishments, evaluation of potential use to the Army, the status of transfer, and additional research required to enhance transfer. The office will also support analyses and feasibility studies for selected accomplishments to stimulate exploratory development.

o Navy - The Office of Naval Research has initiated a new program for the support of academic multi-disciplinary efforts entitled Selected Research Opportunities (SRO-79). Seven topical areas have been identified for primary funding consideration. These will be funded at \$150,000 to \$500,000 annually. The ONR has committed \$3 million out of FY 1979 funds for this program.

The Navy has also initiated a new Summer Faculty Research program to attract University researchers to Navy laboratories.

o Air Force - An emphasis is being placed on multi-investigator programs in universities. These are typified by coherent efforts of a number of people, adequate instrumentation, and technical support in areas of Air Force priority.

Continued emphasis has been placed on Air Force - University research interactions including:

- Summer Faculty Research program
- Summer Design Study
- University Resident Research Program

Starting in the Spring of 1979, an independent review of the in-house basic research programs will be initiated. Only projects having expended at least five labor years of effort in FY 78 will be reviewed during the first cycle. The review will provide input to the Director of AFOSR, the Director of the laboratory, and the AFSC Director of Science and Technology.

2.3 Program Coordination and Technology Exchange - The diverse nature of Research and the number of participants dictate considerable attention to coordination. The fundamental mechanisms are professional interactions of the scientists and engineers. Their active participation is required in scientific society meetings and topical reviews. To foster the interaction, there exists a variety of formal interagency coordinating activities including:

- o Ad hoc working group of the Research Offices of the Military Departments chaired by the Director for Research.

- o Interagency Disciplinary Groups such as the Interagency Materials Group and the Interagency Electronics Group which involves the Departments of Transportation, Energy, and Interior, the National Science Foundation, NASA, and occasionally the National Institutes of Health.

- o Workshops involving laboratory scientists and outside grantees and contractors.

- o Program Reviews held within Military Departments and by the ODUSDRE. Plans are underway to additionally hold Research Topical Reviews of the Research Program throughout the year. The purpose of these topical reviews is: to provide greater visibility to our program, help us improve the communications with the research community, and, most importantly, to help us solicit new ideas and people interested to work on DoD problems.

2.4 Intelligence Assessment - The Soviet Union continues to be the most formidable international scientific competitor to the United States. Since the 1960's the Soviet leadership has stressed the significance of science and technology as a basis for economic and military growth. During a significant portion of this period the United States policy regarding science relaxed, with even some hint of disenchantment towards science and technology. In the last several years, however, there appears to be a growing interest in the connection

between international economic posture and the U.S. technology base. Concern for increased reliance on science augers well for research. Although there is concern over the long-term effects of the "Science Recession" it appears that the U.S. continues its preeminence over the Soviet Union in science. There do, however, exist disciplines, for example mathematics, for which such a statement may not be valid.

The following list characterizes the strengths and weakness of the Soviet research effort:

- o A Soviet strength is their vast pool of science and technology manpower which exists and continues to grow more rapidly than in the U.S. Moreover, the current trend is toward quality of education and productivity.

- o There exists a heavy emphasis on defense related manpower in the physical and natural sciences.

- o In the most important subfields of pure mathematics research, there is quality comparable to or superior to leading Western countries.

- o Great emphasis is placed on cybernetic theory.

- o Emphasis is placed on environmental research which influences military operations including oceanography, atmospheric and terrestrial sciences.

- o A significant investment is made in physics and related areas such as geophysics, astrophysics, physical chemistry, and biophysics. The Soviet contributions in areas such as lasers, low temperature physics, plasma physics and materials are well publicized.

- o A weakness is their continued misuse of qualified specialists and technicians. This impedes innovation and productivity.

- o In spite of the stress on science and technology, continued problems of technological innovation plague the Soviet Union. This situation is well appreciated by Soviet leadership and may be on the way to being corrected.

- o Soviet medical research continues to lag behind the West in most fields.

- o A chemical science program which suffers from the inability to translate innovative technology into production.

3. MANAGEMENT STRATEGY

3.1 Corrective Actions Underway or Planned for FY 1980 - The major thrust for FY 1980 will continue to focus on the goal of making the Research Program a source of new concepts having the potential of drastically improving military capability. This will require increased attention to long-term Research efforts with top scientific

priority. Consequently, it will be necessary to set the environment in the Department and all its components. Several initiatives include:

- o DoD Policy statement concerning the Department's interest in a vigorous Research effort with particular focus on high scientific priority tasks, and the fostering of excellence

- o An aggressive campaign to promulgate the policy of long-term Research among the Military Departments. Particularly, to emphasize the role of Research as the origin of new options, rather than as an add-on or in support of development

- o Promulgation of the unique roles of the various performers to emphasize their strengths

3.2 Long-Term Recommendations - The discussion of program strengths and weakness suggests that a number of other problems be addressed, some of which will undoubtedly be current beyond FY 1980:

- o The multiple support of chief investigators by two or more Military Departments, particularly where the support is substantial, should be given attention. Usually these involve first rate scientists who receive support over a long period of time. A mechanism needs to be designed to give the individual Military agency continued

"access" to the programs and continued flexibility in the funding decision, but which reduces the burden on the investigator for proposal and reporting requirements.

- o The spread of the Army's research effort over so many laboratories is extreme. This emphasizes technology pull rather than push of research within the Army R&D community. It is recommended that the Army Research Office be given increased responsibility in managing the Army DRS program.

- o The expenditures for new capital equipment within the DoD research community are approximately 5 percent of the Research budget. This implies an equipment turnover of $1/.05$, or once every twenty years! A more realistic estimate of an average experimental effort is an equipment turnover of once every five to ten years, suggesting that experimental programs should dedicate 15 to 20 percent of the budget to new capital equipment expenditures. Consequently it is recommended that capital equipment expenditures be increased to at least 7 percent in FY 1980 and 12 percent in FY 1981.

Table I
RESEARCH (6.1) FUNDING

	(\$ Millions)		
	<u>FY 78</u>	<u>FY 79</u>	<u>FY 80</u> (estimated)
Army	107.0	116.3	136.2
Navy	172.1	191.4	224.2
Air Force	95.1	104.9	122.2
DARPA	41.2	63.0	89.2
Other 6.1	<u>0.9</u>	<u>1.0</u>	<u>1.6</u>
DoD Total	416.3	476.6	573.3
% Growth		14	20
% Real Growth*		7	13

* DoD Inflation Factors used to obtain real growth

Table II
MILITARY SERVICES FUNDING RESEARCH (6.1)

		(\$ Millions)		
		<u>FY 78</u>	<u>FY 79</u>	<u>FY 80</u> (estimated)
<u>Army</u>				
61101A	ILIR	14.7	16.0	17.5
61102A	DRS	<u>92.3</u>	<u>100.3</u>	<u>118.7</u>
		107.0	116.3	136.2
<u>Navy</u>				
61152N	ILIR	16.7	17.9	19.4
61153N	DRS	<u>155.4</u>	<u>173.5</u>	<u>204.7</u>
		172.1	191.4	224.1
<u>Air Force</u>				
61101F	ILIR	7.4	8.2	9.0
61102F	DRS	<u>87.7</u>	<u>96.7</u>	<u>113.2</u>
	TOTAL	95.1	104.9	122.2
%	ILIR Growth/Yr		9	9
%	DRS Growth/Yr		10	10
%	TOTAL Growth/Yr		10	17

Table III
DOD PROGRAM FUNDING (FY 80)

	(\$ millions)
	<u>FY 80</u>
PHYSICS, RADIATION SCIENCES, ASTRONOMY, ASTROPHYSICS	79.4
MECHANICS AND ENERGY CONVERSION	58.7
MATERIALS	53.2
ELECTRONICS	51.9
OCEANOGRAPHY	48.9
BIOLOGICAL AND MEDICAL SCIENCES	46.6
CHEMISTRY	41.7
MATH AND COMPUTER SCIENCES	37.5
TERRESTRIAL SCIENCES	19.2
ATMOSPHERIC SCIENCES	17.2
BEHAVIORAL AND SOCIAL SCIENCES	18.1
AERONAUTICAL SCIENCES	<u>10.2</u>
SUBTOTAL	482.6
DARPA	89.2
USUHS	<u>1.6</u>
TOTAL	573.4

Table IV
RESEARCH FUNDING BY PERFORMER

(Percent of Military Department Total)

	<u>FY 78</u>	<u>Estimated FY 79</u>	<u>Estimated FY 80</u>
University			
Army	30.8	31.9	33.1
NAVY	49	52	52
Air Force	52	53	55
Industrial			
Army	6.2	6.5	7.5
Navy	12	12	12
Air Force	20	20	21
In-house			
Army	60.8	59.5	57.4
Navy	34	32	32
Air Force	25	24	21
Nonprofit			
Army	2.2	2.1	2.0
Navy	5	4	4
Air Force	3	3	3

Table V

FUNDING SIZE DISTRIBUTION OF WORK UNITS

	(\$ thousand)				
	0-25	26-50	51-75	76-100	101-150
Number of Army Work Units ^a	62	458	92	6	9
Number of Navy Work Units ^b	430	583	275	108	58
Number of Air Force Work Units ^c	269	343	350	114	33

^a Army Research Office Only. Data as of December 31, 1978

^b FY 78. Represents total funding of \$92.2 million

^c Annual funding, research only (excluding conferences)

GLOSSARY

AF	Air Force
AFAPL	Air Force Aero Propulsion Laboratory
AFOSR	Air Force Office of Scientific Research
AFSC	Air Force Systems Command
AGED	Advisory Group on Electronics
ARO	Army Research Office (Durham N.C.)
ASW	Anti Submarine Warfare
CCD	Charged Coupled Devices
CNR	Chief of Naval Research
DARCOM	United States Army Materiel Development and Readiness Command
DARPA	Defense Advanced Research Projects Agency
DNA	Defense Nuclear Agency
DoD	Department of Defense
DoE	Department of Energy
DRS	Defense Research Sciences
FY	Fiscal Year
GaAs	Gallium Arsenide
HDL	Harry Diamond Laboratory
INP	Indium Phosphide
ILIR	In-house Laboratories Independent Research
JSEP	Joint Services Electronics Program
MAS	Mission Area Summaries
MBE	Molecular Beam Epitaxy
NASA	National Aeronautics and Space Administration
NATO/DRG	Defense Research Groups
NAVAIR	Naval Air Command
NAVSEA	Naval Sea Command
NAVMAT	Naval Materiel Command
NAVMED	Naval Medical Command
NAVELEX	Naval Electronics Command
NBL	Naval Biological Laboratory
NORDA	Naval Ocean Research and Development Activity
NRL	Naval Research Laboratory
NSF	National Science Foundation
ODCSPER	Deputy Chief of Staff, Personnel (Army)
ODCSRDA	Office of Deputy Chief of Staff, Research Development & Acquisition (Army)
ONR	Office of Naval Research
OPNAV	Naval Operations
OSD	Office of the Secretary of Defense
OUSDRE	Office of the Under Secretary of Defense for Research and Engineering
OXRs	Acronym for the Office of the Scientific Research in the Military Departments
PE	Program Element

GLOSSARY (Continued)

P&PGM	Planning & Programming Guidance Memorandum
R&D	Research and Development
RDTE	Research, Development, Testing and Evaluation
SRO	Selected Research Opportunities
TAD	Technical Area Description
TCP	Technology Coordination Papers
TTCP	The Technology Coordination Program
U.S.	United States of America
USSR	Union of the Soviet Socialist Republics

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