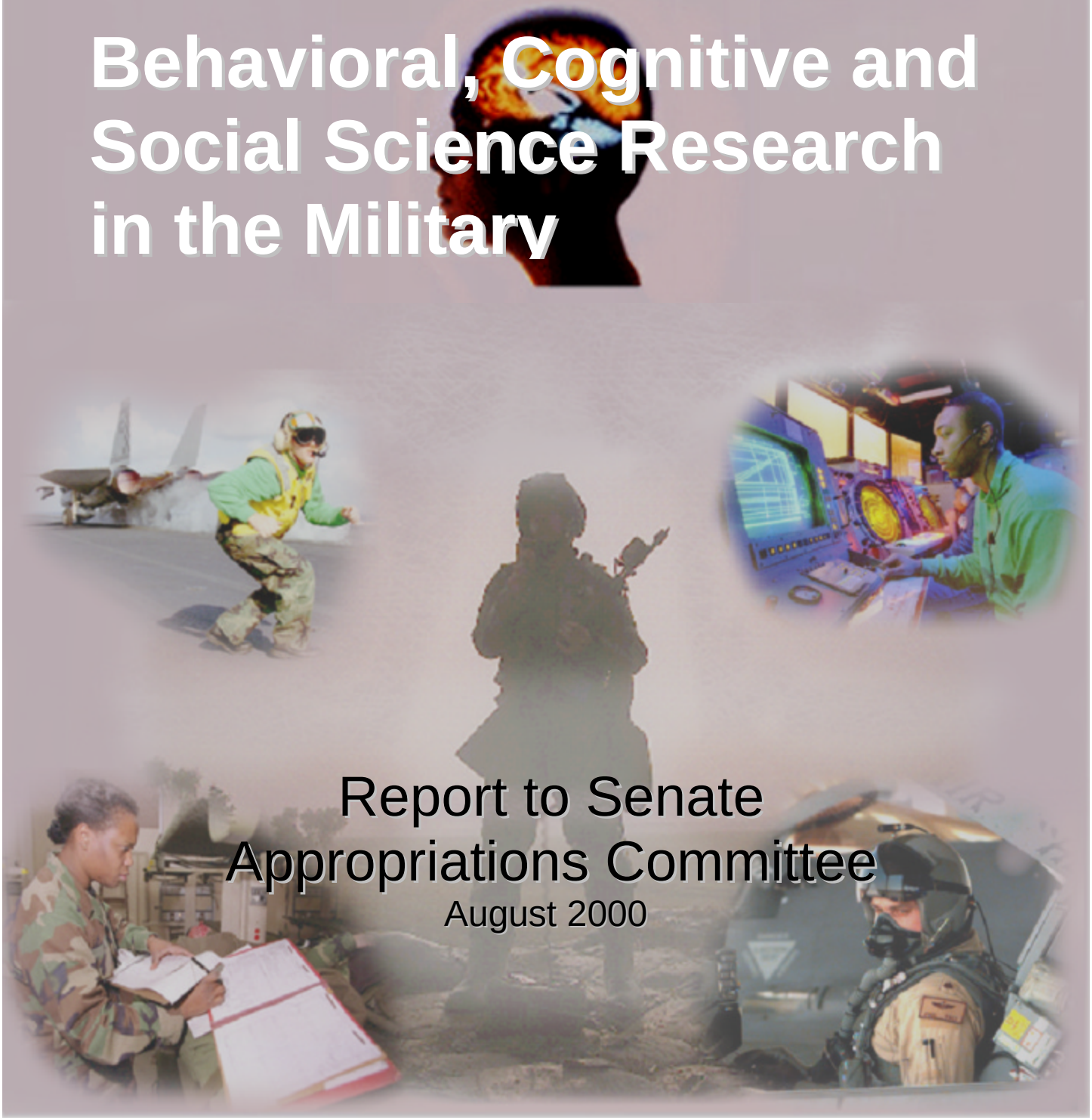
Behavioral, Cognitive and Social Science Research in the Military



Report to Senate Appropriations Committee

August 2000

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Conflict is, and will remain, essentially a human activity in which man's virtues of judgment, discipline and courage – the moral component of fighting power – will endure. To out-think, break, and if necessary, kill an opponent, whilst retaining the moral high ground, will be fundamental – if not essential – to success. It is difficult to imagine military operations that will not ultimately be determined through physical control of people, resources and terrain – by people. Thus NATO will continue to demand high standards of leadership, the core values of selflessness, self-reliance, moral and physical courage and integrity, and an ethos of fighting spirit in its soldiers. A challenge to NATO lies in the erosion of these qualities by the changing nature of contemporary values in its Western Society. Implicit, is the enduring need for well-trained, well-equipped and adequately rewarded soldiers. New technologies will, however, pose significant challenges to the art of soldiering: they will increase the soldier's influence in the battlespace over far greater ranges, and herald radical changes in the conduct, structures, capability and ways of command. Information and communication technologies will increase his tempo and velocity of operation by enhancing support to his decision-making cycle. Systems should be designed to enable the soldier to cope with the considerable stress of continuous, 24-hour, high-tempo operations, facilitated by multi-spectral, all-weather sensors. However, technology will not substitute human intent or the decision of the commander. There will be a need to harness information-age technologies, such that data does not overcome wisdom in the battlespace, and that real leadership – that which makes men fight – will be amplified by new technology. Essential will be the need to adapt the selection, development and training of leaders and soldiers to ensure that they possess new skills and aptitudes to face these challenges.[1]

[1] From NATO RTO-TR-8, Land Operations in the Year 2020, March, 1999

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Executive Summary

The Senate Report 106-53, accompanying the Department of Defense Appropriation Bill, 2000, page 131, requested the Department of Defense (DoD) to conduct an evaluation of the application and benefits of behavioral, cognitive and social science research in the military. This reporting requirement was based on the Committee's concern that DoD support for this area of research is eroding. (Appendix A contains the pertinent language from the SAC report.)

For this report, behavioral, cognitive and social science research was operationally defined and scoped to include DoD institutional investments in (a) Service basic research (6.1) thrusts in cognitive and neural science, human performance, personnel, and training; and (b) applied research (6.2) and advanced technology (6.3) involving manpower, personnel, training, and human factors (but not safety, protection, logistics or medical). The elements reviewed were past, present, and projected funding (FY94-FY00 actual, FY01-FY05 PBR-01), programmatic content, and application and impact. Numerous information sources were utilized, including pertinent literature in the field, DoD science and technology planning documentation, published funding documentation, and published studies and reports.

Behavioral, cognitive and social science research comprises approximately 60 percent of the DoD Human Systems (HS) Science and Technology (S&T) Area and 100 percent of the Cognitive and Neural Science Basic Research Area. Hence, results from the Department's Technology Area Reviews and Assessments (TARAs) for these two areas, completed in May 2000, were included in formulating this response.

The report concludes that (a) the requirements for maintaining strong DoD support for behavioral, cognitive and social science research capability are compelling; this area of military research has historically been extremely productive and return on investment is particularly high; funding in this area achieves stability in PBR-01; and behavioral, cognitive and social science research has produced, and will continue to produce, products with high operational impact. Therefore, it is recommended that Congress continue to support the President's budget request for the science and technology program of the Department.

1. Introduction

Senate Report 106-53 requested the Department to conduct an evaluation of the application and benefits of behavioral, cognitive and social science research in the military. (Senate Report 106-53 to accompany the Department of Defense Appropriation Bill, 2000, page 131. See Appendix A for pertinent language.) The Committee was concerned with the continuing erosion of the Department's support for research on individual and group performance, leadership, communication, human-machine interfaces, and decision-making.

It must be noted that it is exceedingly difficult to isolate and quantify the exact amount of DoD S&T investment in behavioral, cognitive and social science research. This area of research and development (R&D) comprises a body of research that does not fall neatly into typical taxonomies of warfighting mission areas and their associated funding streams. Rather, it often involves a mix of science and technologies that are applied ubiquitously to "human-enable" almost all military mission areas and weapons systems. Hence, this type of research investment is often applied in development programs but rarely documented or accounted for in a fashion that directly breaks-out its discrete thrusts, accomplishments, contributions or funding.

The sources of official DoD budget data used for this report are the Components' R-2 Exhibits[1]. These exhibits are uniquely useful in that they map detailed programmatic content with dollars. However, even these documents vary considerably both within and across DoD components in the degree of programmatic content that can be extracted for a report on a technology area.

In responding to the Committee's request, the Department conducted a review of its institutional investments in behavioral, cognitive and social science research, including past, present and projected funding[2], programmatic content, application and impact. These research areas comprise approximately 60 percent of the DoD Human Systems (HS) Science and Technology (S&T) Area and 100 percent of the Cognitive and Neural Science Basic Research Area. Hence, results from the Department's Technology Area Reviews and Assessments (TARAs) for these two areas, completed in May 2000, were included in formulating this report.

For this report, behavioral, cognitive and social science research was operationally defined and scoped to include: (a) Service basic research thrusts in cognitive and neural science, human performance, personnel, and training; and (b) applied research and advanced technology development involving manpower, personnel, training, and human factors (but not safety, protection, logistics or medical). The report was generated by reviewing numerous information sources, including: pertinent past and present literature in the field, DoD science and technology planning documentation, published studies and reports, and findings from the recent DoD Human Systems TARA.

In summary, the report provides an evaluation of the application and benefits of behavioral, cognitive and social science research in the military. Chapter 2, Background, provides a general explanation for why behavioral, cognitive and social science research is supported by the Services. Chapter 3, Defense S&T Reliance, discusses the history, architecture and overarching processes

[1] R-2 Exhibits provide narrative information for all RDT&E program elements and projects within each Component's RDT&E program except the classified program elements.
[2] FY94-FY00 actual funding was derived from R-2 Exhibits and PBR-01; FY01-FY05 funding was estimated from R-2 project histories and PBR-01.

through which DoD corporately plans and executes military S&T. Chapter 4, Continuing Requirements, provides discussion and results from a number of assessments, conducted both internally and externally to DoD, on the continuing requirement for military behavioral, cognitive and social science research. Chapter 5 provides an extended discussion of the problem solving history of military behavioral, cognitive and social science investments and summary findings from the HS and the Basic Research TARAs. Chapter 6 examines dollar amounts of institutional investments in behavioral, cognitive and social science research across the military S&T base and assesses general funding issues. Chapter 7 provides a report wrap-up with summary conclusions.

2. Background

DoD support for research in the behavioral, cognitive and social sciences began during World War I when the need was recognized for a testing device that could quickly determine the skills of recruits. Enlistment, training and deployment needed to occur in a short space of time, and optimum placement was a necessity. The test that emerged, the Army Alpha Test, is the great grandfather of today's defense-wide instrument for determining the skills and aptitudes of all who enter the Armed Services, the Armed Services Vocational Aptitude Battery or ASVAB. The continuing military-supported work on testing has not only enabled the Services to make efficient decisions about training and placement as times and needs have changed, it has also built the theoretical base for all aptitude testing, military and civilian. The ASVAB, the Scholastic Achievement Tests, the Graduate Record Examination, all owe their existence to research supported for its own needs by the Armed Services.

Today we have "smart" tests that are computer-administered and that can profile the strengths and weaknesses of a candidate for training very precisely. With such precision, high quality training tailored to the particular skill profile of the trainee can be carried out in record time. Now we are developing "embedded training" devices so that the skills of personnel can be honed in the field using the equipment that they will use in battle. We look back on the Army Alpha as a quaint artifact generated at the beginning of the last century. But without that beginning, today's selection, training, and deployment procedures would not be possible.

This illustration of service support for behavioral, cognitive and social science research and its applications illustrates three things about the support:

1. The research has always been aimed at meeting military needs;
2. It often results in benefit to the civilian sector as well; and
3. The research is carried out in a dynamic environment that necessitates continued research to make improvements as needs change, or to address new requirements, or to prepare for requirements that are not yet known.

The Services support behavioral, cognitive and social science research to help assure that the Services will have the knowledge and procedures to defend the country at the time we need them.

Military knowledge needs are not sufficiently like the needs of the private sector that retooling behavioral, cognitive and social science research carried out for other purposes can be expected to substitute for service-supported research, development, testing, and evaluation. More importantly, while some industries maintain laboratories aimed at carrying out research that leads to new products, industry does not maintain laboratories devoted to behavioral, cognitive and social science research. Moreover, it only rarely supports university-based behavioral, cognitive or social science research. The practice in U.S. industry is to contract for services related to human resources development. The result is that industry purchases the products of behavioral, cognitive and social science research produced originally through federal support. Because it does not support the research base in these areas, industry often receives services based on non-current research, or, in the worst cases, based on no research at all. The bottom line is that in behavioral, cognitive and social science research, there is little defense-relevant research "on the shelf" to buy. Our choice, therefore, is between paying for it ourselves and not having it.

While the National Science Foundation (NSF) and the National Institutes of Health support

behavioral, cognitive and social science research, their research products only occasionally are useful for military needs. For example, the cognitive research supported by NSF has provided valuable basic knowledge about cognition. But the military need for science in this area outstrips NSF's capabilities. NSF funds basic research. We want smart circuitry that will allow tiny robotic flying devices to carry out reconnaissance. We want cost-efficient training simulators that train service men and women in record time. We want devices ergonomically engineered so that troops with many levels of ability will be able to use increasingly complex equipment safely and effectively. We want to know how to prepare recruits with less than a high school education to function in high-technology-dominated environments. We want to know how best to train soldiers for peacekeeping missions and how those techniques differ from training soldiers to take part in war. We want to understand the typology of leadership and to use that knowledge to put the right kinds of leaders in the right kinds of leadership positions. And the list goes on. Behavioral, cognitive and social science research that is not supported by the Services sometimes carries us the first step or two toward our many applied goals, but there is a vast distance we cannot traverse unless we take the steps ourselves.

Besides the unavailability from the non-defense sector of the specialized behavioral, cognitive and social science knowledge we require, we also support this research because we must be sure we have this knowledge when we need it. We must attend to updating knowledge continually as systems, equipment, and policies change. We must sustain work in areas where our understanding remains inadequate (as described in the Department's S&T Planning documentation). And we must use research to prepare for challenges we cannot foresee by creating a versatile knowledge base capable of application to a variety of eventualities.

As with all science, assuring behavioral, cognitive and social science knowledge will be there when it is needed, means beginning to acquire that knowledge well before it is needed. The ability to maintain such timeliness depends on stability because research takes time and requires people who have keen insight into the interfacing of knowledge and application. We must work toward stability in S&T funding if we are to maintain the ability of our military men and women to defend the country against any foe and to work with our friends to achieve and maintain peace.

3. Defense S&T Reliance

Defense S&T Reliance is the current overarching integrating process through which DoD corporately plans and executes S&T. Its history, architecture and processes are discussed in this chapter as a basis for understanding and assessing the efficacy of the management controls that DoD employs to ensure the effectiveness and efficiency of its S&T enterprise, to ensure high return on its investment, and to ensure the satisfaction of broader national S&T interests. The Reliance process covers the breadth of S&T technical areas within DoD, but for purposes of this report, only those components and processes pertinent to behavioral, cognitive and social science research will be elaborated. This coverage will help to elucidate the technical scope and operational definition of the research that has been counted for purposes of this report as comprising DoD's institutional investment in the general disciplines of behavioral, cognitive and social science research.

3.1 The Origins of Reliance

In October 1989, the Deputy Secretary of Defense (DEPSECDEF) issued a draft of Defense Management Report Decision 922 (DMRD 922), which challenged the Services to create a new approach to S&T management that would increase efficiency and reduce unwarranted overlap in the Research, Development, Test and Evaluation (RDT&E) activities of the Services.

The Services moved quickly to respond to the challenges of the draft DMRD 922. In October 1989, just after issuance of the draft Decision, the Services began formal discussions on ways to further strengthen inter-Service cooperation in their RDT&E programs and increase the use of each other's facilities. One of these studies was called "Project Reliance," which was undertaken by the Army and Air Force to examine opportunities to consolidate and collocate their R&D efforts at single-site locations in selected technology areas. Project Reliance was ultimately expanded to include the Navy and became Tri-Service S&T Reliance.

By the summer of 1990, the three Services had jointly developed a coordinated proposal for the Deputy Secretary of Defense that further outlined approaches to RDT&E laboratory consolidation and inter-Service Reliance in both S&T and T&E. The DEPSECDEF approved the Tri-Service-coordinated proposal in concept, and the Services tasked individual groups to identify ways to achieve laboratory consolidation within the Services and achieve greater inter-Service Reliance for S&T and T&E. On 12 October 1990, the formal Tri-Service S&T Reliance study began and addressed the full range of the Services' S&T activities, namely their 6.1, 6.2, and 6.3A programs.

In November 1990, the DEPSECDEF signed the final version of DMRD 922, which formally endorsed the inter-Service Reliance initiative, acknowledged the savings already achieved by the individual Service consolidation initiatives, and tasked the Services to proceed with plans for further restructuring and streamlining their RDT&E activities.

3.2 TAPSTEM

In response to the challenge of limited resources and calls for greater efficiency, the Services, functioning under Project Reliance, sorted the various people-focused technologies into several distinct categories and required that an overall architecture and management structure be developed for each of these elements. In November 1990, the general technology areas of manpower and personnel, education and training, and simulation and training devices were combined under a common management structure called the Training and Personnel Systems Technology Evaluation

and Management (TAPSTEM) Committee. Within that management structure, two major inter-service coordinating groups were developed, one dedicated to Manpower and Personnel research and development, and one for Training Systems research and development. Hence, TAPSTEM, with the exception of human factors research, subsumed the spectrum of DoD institutional investments in the behavioral, cognitive, and social sciences. The primary objectives of TAPSTEM were:

- To increase effectiveness and efficiency in service resource utilization.
- To address organizational roles and resolve service organizational / functional alignment issues.
- To ensure program relevance and obviate duplication via a timely review process.
- To define service issues that require resolution / coordination with other federal agencies outside TAPSTEM.

Under the TAPSTEM agreement, and as a result of Reliance implementation, individual Service laboratory programs were changed based upon laboratory strengths to reflect "lead" service assignments. As of late 1993, mutually agreed upon Service primary responsibilities were assigned as depicted in Figure 1. In the mid-1990s the TAPSTEM's role and responsibility was rolled into the HS Reliance Panel.

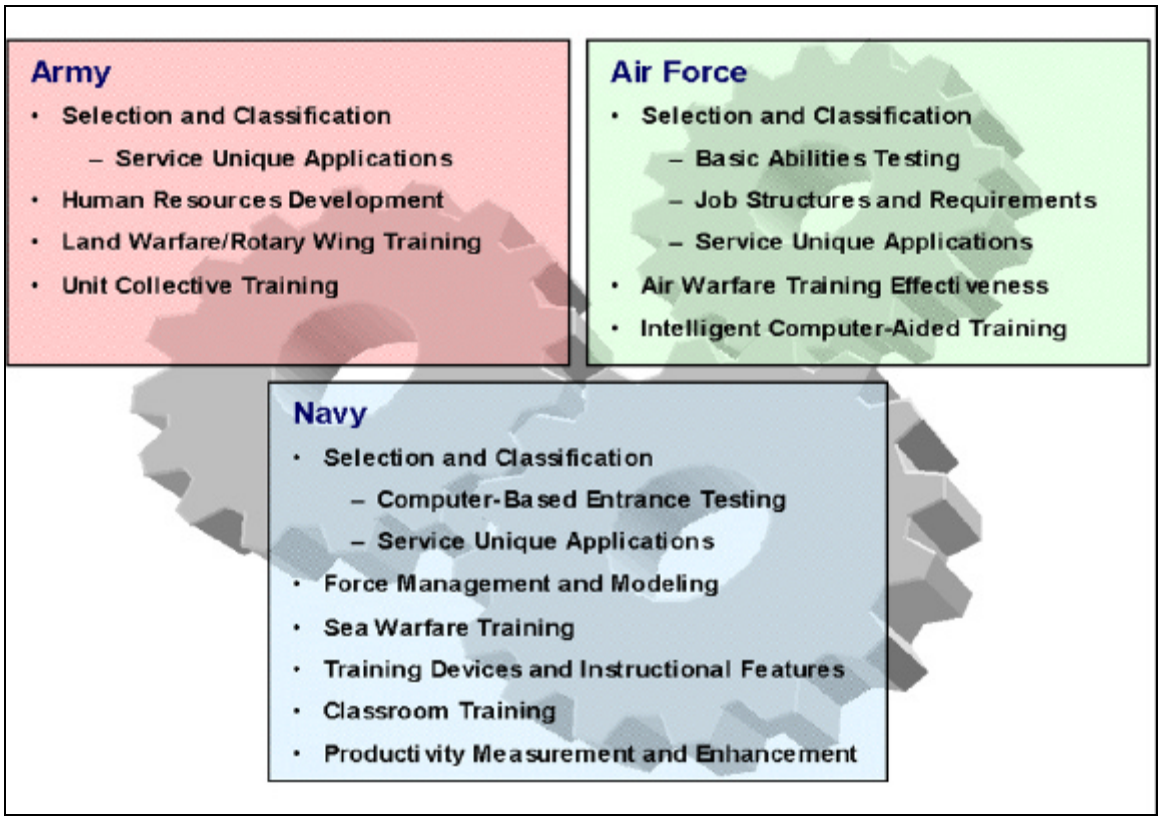

Figure 1. TAPSTEM 1993 "Lead" Service MPT S&T Assignments.

3.3 DoD Management of S&T Reliance

In 1995, Project Reliance began to evolve into a more comprehensive process. The Director, Defense Research and Engineering assumed responsibility for management and formed a new strategic planning process for the entire S&T Program. The foundation of this process is the *Defense S&T Strategy*, which along with its supporting *Basic Research Plan (BRP)*, *Joint Warfighting S&T Plan (JWSTP)*, and *Defense Technology Area Plan (DTAP)*, present the DoD S&T vision, strategy, plan, and objectives for planners, programmers, and performers of Defense S&T. As shown in Figure 2, the strategy and plans and supporting individual S&T master plans of the military services and defense agencies guide the annual preparation of the defense program and budget.

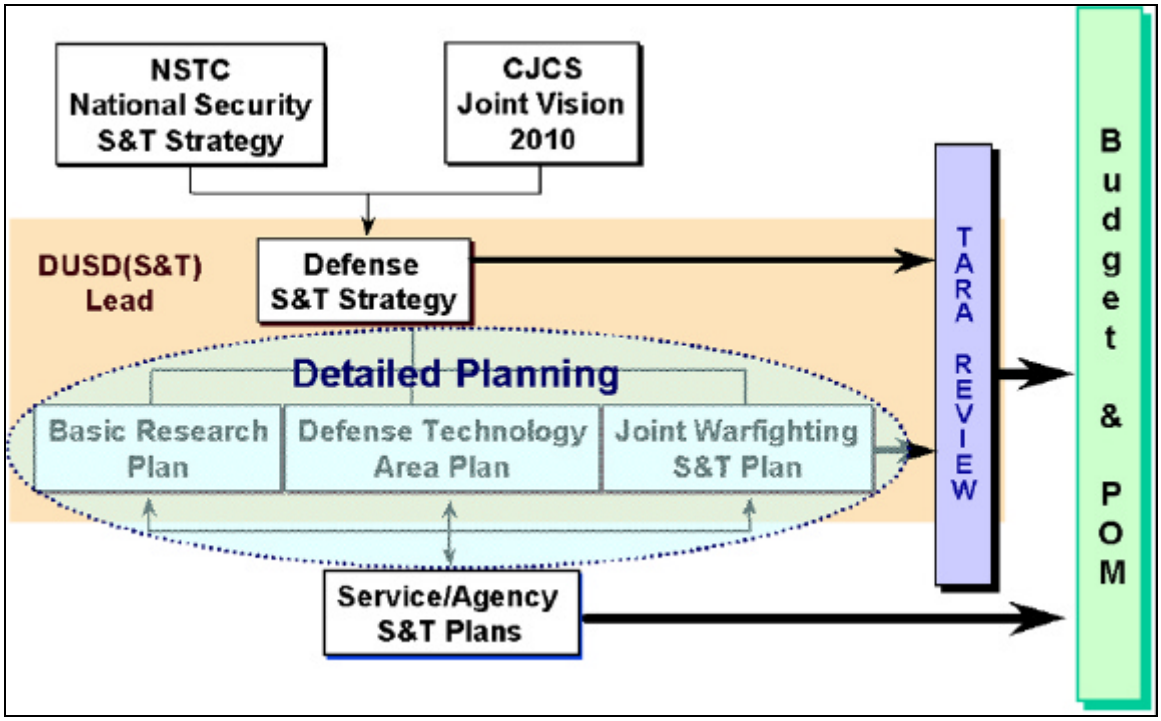

Figure 2. Integrated Defense S&T Planning Process.

The BRP presents the DoD objectives and investment strategy for DoD-sponsored Basic Research (6.1) performed by universities, industry, and service laboratories in each of 10 technical disciplines. The cognitive and neural science technical area in the BRP encompasses military basic research in the behavioral, cognitive and social sciences.

The JWSTP takes a joint perspective horizontally across the Service and Defense Agencies to ensure support for the requisite technology and advanced concepts for superior joint and coalition warfighting. It ensures that the near-, mid-, and long-term needs of the joint warfighter are properly balanced and supported in the S&T planning, programming, budgeting, and assessment activities of the DoD.

The DTAP presents the DoD objectives and the investment strategy for applied research (6.2) and advanced technologies (6.3) critical to DoD acquisition plans, service warfighter capabilities, and

the JWSTP. The DTAP takes a horizontal perspective across Service and Defense Agency efforts, thereby charting the total DoD investment for a given technology. The anticipated return on investment is identified through some 300+ Defense Technology Objectives (DTO) in 11 broad technology areas. (The Human Systems technology area, to be discussed in more detail below, subsumes applied research and advanced technology demonstrations in the behavioral, cognitive and social sciences.) These DTOs identify the specific technology advancements that will be developed and/or demonstrated, the date of expected technology availability, and the specific military benefits resulting from the technology advance. Issued annually as Defense Guidance, the DTAP identifies the advanced concepts and technologies that are essential to enhancing high-priority joint warfighting needs and that will receive funding priority in the President's Budget and accompanying Future Years Defense Plan (FYDP).

Figure 3 shows a flow chart of the S&T Reliance process. It includes separate assessments of each of the 11 technology areas by independent assessment groups, the Technology Area Review and Assessment (TARA) panels, convened specifically for the particular technology area and composed of senior, non-DoD engineers and scientists, as well as selected OSD personnel. The purpose of the TARA is to assess the integration of programs, reduce unnecessary duplication, and recommend opportunities for improved synchronization and synergy. Issues that cannot be resolved within the Reliance area are raised to the Defense S&T Advisory Group (DSTAG). The results of the Reliance planning and review processes form the input to the Services' investment strategies along with supplemental S&T requirements guidance from within each Service.

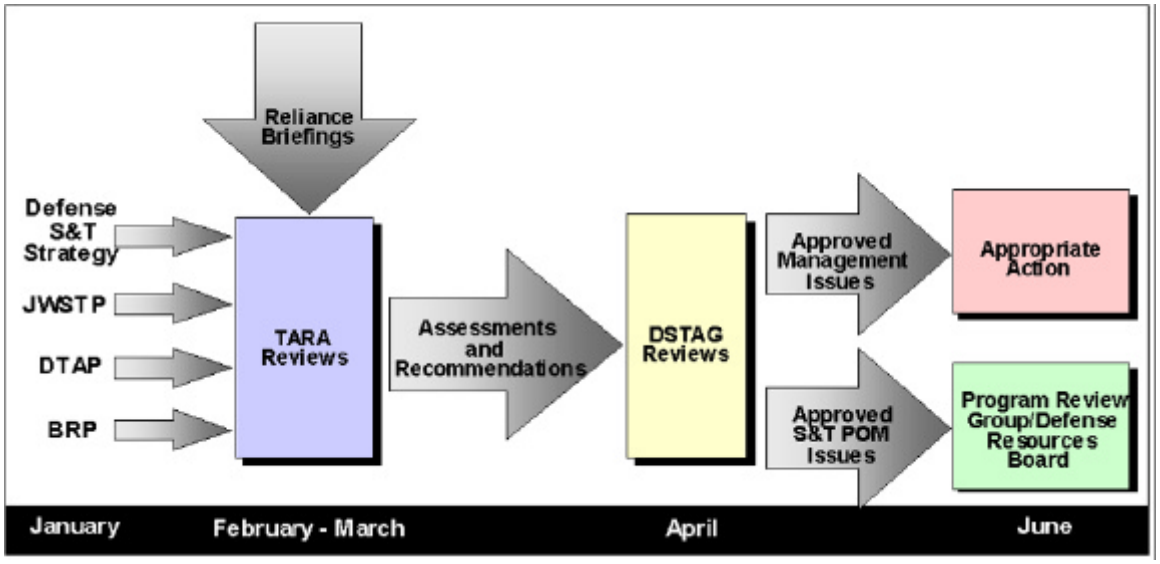

Figure 3. Defense S&T Reliance Process.

3.4 Behavioral, Cognitive and Social Science Research within Reliance

3.4.1 Basic Research

As discussed in the previous section, behavioral, cognitive and social science basic research is organized and managed under the BRP taxonomy in the *Cognitive and Neural Science (CNS)* strategic research area. The DoD-wide program of research in CNS develops the science base enabling the optimization of the services' personnel resources. Areas of application include testing, training, and simulation technologies; display support for target recognition and decision making;

techniques to sustain human performance; human factors; and team/organizational design and evaluation methodologies. Basic research activities in CNS are generally classified into the two subareas of (1) Human Performance and (2) Reverse Engineering. Table 1 provides an outline of service-specific interests and commonality in the CNS area.

Subarea	Army	Navy	Air Force
Human Performance			
Personnel Selection Training Human-System Integration Teams and Organizations	Leadership Societal Linkages	Tactile Information Processing Sensory-Guided Motor Control	Chronobiology Neuropharmacology
	Areas of Common Interest: Teams and Organizations (A, N, AF); Cognition, Learning, and Memory (A, N, AF); Stress and Performance (A, AF); Auditory and Visual Perception (A, N, AF)		
Reverse Engineering			
Machine Vision Autonomous Vehicles Automatic Target Recognition Tele-Robotics	None	Autonomous Undersea Vehicle / Manipulators Neural Computation Plasticity Automatic Sonar Classification	3D Audio Displays Infrared Biosensors
		Areas of Common Interest: Machine Vision (N, AF)	

Table 1. Service-Specific Interests and Commonality in Cognitive and Neural Science

3.4.1.1 Human Performance

Research in human performance influences the Services' approach to personnel selection, assignment, and training. It also explores ways to augment personnel performance in military environments and to develop new ways of organizing better, more effective teams and command and control organizations.

In research on teams and organizations, the Army concentrates on group-leader processes, the Navy on coordination in distributed groups and models for evaluating organizational design, and the Air Force on communication strategies and interfaces important to maintaining situational awareness. In the areas of cognition, learning, and memory, the Army concentrates on training principles that underlie acquisition, retention, and transfer of soldier skills. The Navy emphasis is on artificial intelligence and AI-based models of cognitive architecture. The Air Force focus is on sensory and perceptual systems to enhance human-machine interaction, cognitive dimensions of team performance, and cognitive performance modeling and prediction.

In stress and performance research, the Army focuses on performance issues, while the Air Force focuses on the circadian timing system underlying fatigue, performance, and the change from sleep to arousal. The Army vision and audition program seeks to optimize the user interface in visual control of vehicles and reduce the effects of intense sound. Navy research focuses on teleoperated undersea requirements, automatic target recognition for precision strike missions, and auditory pattern recognition for sonar signal analysis. More generic principles of human image communication and sound localization are being investigated by the Air Force.

3.4.1.2 Reverse Engineering

The reverse engineering subarea exploits the unique designs of biological neural systems by discovering novel information processing architectures and algorithms potentially implementable in engineered systems. These efforts seek to imbue machine systems with capabilities for sensing, pattern recognition, learning, locomotion, manual dexterity, and adaptive control that approximate human functionality. The current Navy program in reverse engineering combines neurosciences and computational modeling in five topical areas: vision, touch/manipulation, locomotion, acoustics/biosonar, and learning. The Air Force examines biological sensor system specificity and

sensitivity to provide, for example, new technologies for ambient-temperature, lightweight, low-cost infrared sensors by examining the mechanisms used by animals to detect IR signals.

3.4.2 Applied Research and Advanced Technology Development

Human Systems is one of the 11 technology areas that are identified in the DTAP taxonomy. It provides technologies and methods to ensure that the military's most critical resource—its people—are properly selected, trained, and equipped to perform as effectively and as safely as possible. Cost reduction through more efficient use of personnel and equipment is a key secondary goal. Air Force, Army and Navy are the primary investors in the Human Systems technology area. While DARPA is involved in collaborative work with the Services in this area, it does not identify any institutional investments in the Human Systems technology area. Human Systems is organized into four subareas that provide a logical construct for enhancing cross-service coordination in this multifaceted technology area:

- *Information Display And Performance Enhancement (ID&PE)*
  Supports future joint and service-unique warfighting needs in data visualization and situational understanding, aural and visual interface, immersive interface, intelligent aiding and decision support, decision-centered staff process control, supervisory control and teleoperation, and physical aiding.

- *Design Integration And Supportability (DI&S)*
  Supports the fielding of affordable, effective equipment needed for future military operations and support by advancing the state of the art in human system design tools, performance requirements estimation, performance metrics, human-system integration, logistics readiness, and sustainment logistics.

- *Personnel Performance And Training (PP&T)*
  Strengthens unit readiness and reduces costs (e.g., selection, school/job assignment, retention) through advances in force management and modeling, selection and classification, human resource development, simulation-based training, training strategies, and training efficiency. (Note: The early organization named TAPSTEM is substantially this panel.)

- *Warrior Protection And Sustainment (WP&S)*
  Supports warfighting and peacekeeping mission capabilities through full spectrum personal protection; troop sustainment, including rations and field feeding equipment; aircraft escape/crash safety, survival and rescue; advanced airdrop (both personnel and cargo); and dismounted, mounted, and aircrew warrior systems integration, including warfighter systems analysis.

Clearly, the bulk of the work within Human Systems extends, applies and demonstrates S&T reasonably considered under the general rubric of behavioral, cognitive and social science research. However, work within the WP&S subarea is a significant exception. This subarea was excluded early on in the analysis for this report, since, while focused on benefiting the warfighter, most of the past and present work in this subarea does not involve behavioral, cognitive and social science research. (This is not to say that in the future it couldn't or shouldn't.) Projects within the other subareas were screened for inclusion or exclusion based on descriptive summaries within the Services' R-2 Exhibits. Appendix B provides funding roll-ups for those programs, projects and thrusts that were ultimately included in this report. Typically, approximately 60 percent of the

Humans Systems investment within a given year was classified as behavioral, cognitive and social science research[1].

3.5 Summary of Report Research Scope

For this report, behavioral, cognitive and social science research was operationally defined and scoped to include Air Force, Army and Navy: (a) basic research thrusts in cognitive and neural science, human performance, personnel, and training; and (b) applied research and advanced technology development involving manpower, personnel, training, and human factors (but not safety, protection, logistics or medical).

[1] Note that some relevant Army program investments included in this report are classified within Reliance as research in the Information Systems technology area rather than the Human Systems technology area.

4. Continuing Requirements

The documentation in support of requirements whose solutions are dependent upon military research in and application of the behavioral, cognitive and social sciences is voluminous. From the National Security Strategy, which mandates the highest priority be placed on ensuring the quality of military personnel, all the way down to the infantryman on the battlefield whose very life depends on the degree to which his equipment was optimized for his/her use and the efficacy of the training provided to employ it, the ubiquity of compelling requirements for human-centered research, design and development is manifest. Moreover, as advanced technology proliferates among both friend and foe we are beginning to see a leveling of the warfighting field through increasing asymmetric threats. This reveals the under-recognized value to the military of behavioral, cognitive and social science research. That is, when the tools of war in and of themselves do not enable massive advantage, the ability to optimally employ them will.

In this chapter we will present support for the continuing requirement for behavioral, cognitive and social science research from a number of sources. First, pertinent requirements generated by the Services and incorporated into the current Human Systems DTAP will be summarized, and second, requirements identified by selected special studies will be reviewed.

4.1 Requirements from the DTAP

As a nation, we have high expectations for our Armed Services. A strategic challenge for DoD is to increase the warfighting capability and adaptability of weapon systems in an increasingly complex, dynamic, and resource-limited national security environment. To meet this challenge, the Services must place increasing emphasis on developing and employing “force multiplying” concepts and capabilities.

One key to force multiplication—and to lethality, survivability, and unit efficiency—is the effective use of human resources. People are the most critical and most costly component of weapon systems; personnel and related costs represent about 40 percent of the annual defense budget. Human-centered science and technology directly contributes to all future warfighting capabilities by optimizing the use and protection of the DoD’s most critical resource—its people. Advances in behavioral, cognitive and social sciences research and application are essential for the Services to meet global commitments in combat and peacekeeping. The impacts of these technologies include increased unit readiness, improved mission performance, reduced casualties, and enhanced mobility.

4.1.1 Information Display and Performance Enhancement

The Information Display and Performance Enhancement subarea goals are: (1) to enhance the warfighter’s situational awareness through exploitation and integration of emerging sensor, display, and processor technologies for organizing, managing, and displaying vast amounts of information; and (2) to greatly enhance mental performance while adapting emerging display and performance technologies to the unique tactical requirements projected for tomorrow’s battlefield. These complementary goals will significantly enhance military performance by optimizing the utility of the information and the ability of the operator.

The ID&PE subarea addresses numerous challenging requirements. These include presenting information (visual, aural, haptic) to the warfighter using intuitive displays. The combat environment compounds the need to present this critical information via easily interpreted displays that do not add to the mental or physical workload of the warfighter. New ways to represent and visualize information extracted from a complex data domain are essential; too many information sources threaten to overwhelm the human capacity to acquire, assimilate, and interpret data. For effective human performance on the digitized battlefield, systems data access must be robust, controllable, and able to convey the right information at the right time and in the right context. Information system displays must be simplified by better matching their organization and content with the experience-based decision making frameworks used internally by commanders and their staffs. Many new technologies are emerging for input and display of information for vehicle crewmembers. These include 3D audio, multiple degree-of-freedom untethered controllers, stereo display technologies, voice recognition, and total immersion in a virtual environment. Designers lack data to assist them in determining the most cost-effective combination of technologies for improving operator performance for the wide range of applications in the military. Alternative control and input methods including touch, speech, eye tracking, and natural language will provide more intuitive display manipulation. Additionally, future information management and display systems must support both horizontal and vertical synchronization of the command staff process so that simultaneous planning becomes a reality, so that this distributed cognitive process remains focused on commander's intent, and so that C^2 processes evolve from merely information driven to decision driven. ID&PE research must also provide an effective bridge between the operational and developmental communities through the refinement of diagnostic performance metrics that focus on the warfighter–information systems interface

Another challenging requirement is to extend warfighter capabilities (physical, cognitive, psychological). Meeting this challenge involves merging existing models of biodynamics and ergonomics with the emerging models of human cognition, individual and organizational decision-making, and combat stress reactions. These parameters must subsequently be transitioned to and integrated with weapon systems models; command, control, communications, computers, and intelligence (C^4I) models; and realistic human-in-the-loop mission scenarios through the DI&S subarea efforts. Additional challenges include accelerating technology maturation for very high speed, real-time mission planning and decision support systems; developing decision support tools to monitor and counter the adverse effects of high operational stress and high operator performance levels; and developing computerized, collaborative, intelligent support systems to enhance performance and decision making on the battlefield and in the battle group. Since target acquisition is a key to successful military operations, performance aids must be developed that, when combined with active and passive sensors, can provide information on the effects that texture, shape, and color have on weapons' signatures. These aids will improve detection and identification of objects in underwater and aerospace environments. Rotorcraft, in particular, often must operate in high-threat scenarios for which the integration of advanced mission equipment functions and data presents a major challenge. Technologies to aid performance will reduce helicopter vulnerability and thus increase survivability and first-time mission success by improving real-time internal situational awareness through data fusion, innovative information presentation, and cognitive decision aids.

4.1.2 Design Integration and Supportability

Design Integration and Supportability subarea goals include designing tools for physical accommodation, devising methods for human error assessment, developing metrics and tools for assessing human performance in relation to mission effectiveness, demonstrating how to achieve

effective crew system integration during design, and developing tools to both streamline and enhance the weapon system support infrastructure at both retail and wholesale levels. The ultimate aim is to improve weapon system effectiveness, availability, and affordability. All of the design integration tools are set in the context of weapon system engineering.

The complexity of warfighter missions and weapon systems has increased as a result of improved sensors, advanced communications and data processing capabilities, increased threats, and more powerful propulsion systems and munitions. A massive amount of human performance data collected over the years could aid in designing systems to deal with this complexity, but these data either are not available to the design integration community or are difficult to locate and interpret. Consequently, integration is performed late in the design process, and evaluations rely on costly physical prototypes. Industry crew station designers lack the analysis and design tools comparable to those available in other disciplines. Models and measures to design for effective human performance are needed, but must link to the computer-aided design/computer-aided engineering (CAD/CAE) tools used in vehicle engineering. Largely due to human variability, quantitatively linking the human interface to system effectiveness is considerably more difficult than establishing such criteria for physical systems.

To improve supportability, maintenance and logistics technical data need to be generated in more cost-effective ways and more intelligently integrated so that maintenance technicians and logisticians can directly intercommunicate with all electronic maintenance systems, obtain all necessary logistics information, and view large schematics at the immediate work site. Shipboard and aircraft maintainers need tools to help interpret information from equipment diagnostic sensors and to make accurate, predictive diagnostics in order to fully realize the potential of just-in-time maintenance. Increased use of software in modern weapon systems requires new approaches to software failure analysis, diagnostics, and automated reconfiguration to “work around” errors when they do occur. Operational strategies that rely less on forward basing and more on rapid projection require significant improvements to asset distribution, pipeline management, and material handling capabilities. Also, the application of human-centered design and logistics support capabilities to space equipment and operations is critical to Joint Vision 2010 realization. In today's budget-constrained operational environment, systems must be designed to be operated and maintained by affordable levels of manpower with affordable training, a definite challenge when estimating human resources in early system formulation.

4.1.3 Personnel Performance and Training

In the Personnel Performance and Training subarea, technical improvements are needed in statistical forecasting, mathematical optimization, information science, and artificial intelligence. Other technical requirements include needed advances in job analysis that identifies mental requirements, self-report and self-inventory measures that resist falsification, more objective measures of mission performance, and battle command performance effectiveness baseline measures.

Predictive measures are needed to determine the effects of simulation on training readiness that cannot be assessed independently of the training program. High-resolution and high-brightness visual systems are needed that can provide cost-effective, realistic imagery to warriors and visual cues in virtual battlefields used for training. Innovative performance measurement and feedback methodologies need to be developed to provide real-time performance data to widely dispersed small units. Novel instructional methods need to be developed to rapidly respond to demands for just-in-time training.

4.2 Requirements from Selected Studies

4.2.1 Optimizing Manning

Commencing in April 1999, the Naval Research Advisory Committee Panel on Optimizing Surface Ship Manning was tasked by the CNO to assess Navy efforts to optimize manning on surface ships. This included a review of previous relevant studies, current programs in US and foreign navies, and relevant technology opportunities.

A major finding was that Navy's Smart Ship demonstrated that technology insertion and process improvements can reduce manning, maintain capability and improve shipboard quality of life. However, the panel also found that Navy has not diffused the Smart Ship lessons learned throughout the Fleet. This was attributed to a lack of top-down leadership and implementation strategy. They reported that this situation highlights the enormity of the problem the Navy faces to adapt the revolutionary changes anticipated in DD-21.

Among the panel's four primary recommendations, three were directly dependent upon the fruits of continued behavioral, cognitive and social science research. The three relevant recommendations were to:

- Modify the ship design process to include human engineering to achieve optimal human / system performance.
- Align R&D efforts so that compatible processes and specifications are incorporated for ship components and subsystems for optimally manned ships.
- Modify recruitment, training, compensation and career progression strategies to reflect changes in organization, skills, and expanded decision-making authority required on optimally manned ships.

4.2.2 New World Vistas: Air and Space Power for the 21st Century

The Air Force Scientific Advisory Board produced a report in 1995 entitled New World Vistas: Air and Space Power for the 21st Century. This report forecast a potential future for the Air Force and identified six technology groups that should be developed to produce Air Force future capabilities necessary to continue into the 21st century as the world's best and most respected. "People" was one of the technology groups identified. Of five recommendations made pertaining to the People technology group, three were directly dependent upon behavioral, cognitive and social science research:

1. Training. Training can be significantly improved and made less expensive through personnel selection and classification technologies that more closely match skills and aptitudes to the task. In addition, interactive individual and group training using virtual reality and other distributed interactive simulation where appropriate will be the training technologies of the 21st century.

2. Human/Machine System Fusion. Voice recognition and voice generation, gesture recognition and response, multilingual translation and generation and brain control of computer technologies will all contribute to making sure that the human is not the limiting factor in rapid exploitation of Global Awareness through Dynamic Planning and Execution Control.

3. Operational. In order to better understand, design and operate the weapon systems of the next century a more detailed understanding of the human is needed. Technologies associated with cognitive and non-cognitive models of the human learner and of the instructional process are needed. Such understanding not only will help with the training needs listed above, but will make possible the most cost effective human machine fusion in such areas as displays and controls, brain control of computers, etc.

4.2.3 Modeling Human and Organizational Behavior

The National Research Council Panel on Modeling Human Behavior and Command Decision-Making: Representations for Military Simulations conducted an 18-month study, beginning in 1996, to review the state-of-the-art in human behavior representations as applied to military simulations, with emphasis on the challenging areas of cognitive, team, and organizational behavior. The panel found that the need to represent the behavior of individual combatants as well as teams and larger organizations is expanding as a result of increasing use of simulations for training, systems analysis, systems acquisition, and command decision-making. In the panel's view, achieving realism requires that models be based on psychological and sociological theory. The panel stated there is a requirement for continued long-term support of theory development and basic research in areas such as decision-making, situation awareness, learning, and organizational modeling.

4.2.4 Training, Leader Development, Soldier Support

In the summer of 1999 an ASAALT Independent Review Team conducted an assessment of ongoing and proposed Army S&T activities that contribute to meeting the Training, Leader Development, Soldier Support (TLS) needs for Strike Force and the Army After Next. Key requirements identified by the study are summarized in Table 2. All of these are addressable through focused behavioral, cognitive and social science research.

Training	Leader Development	Soldier Support
Enduring Problems		
- Reducing the time to train - Improving the effectiveness of training - Promoting cohesion, motivation, and retention - Developing creativity, adaptability, and problem solving skills	- Defining the qualities, and competencies / knowledge, skills and abilities (KSA) to succeed - Developing metrics to measure and predict KSA - Inculcating KSAs early and often - Capitalizing on technologies for education / training / development - Retention of personnel	- Screening for current demographics to optimize selection and first term success - Determine if contemporary approach is most effective and efficient way of accessing personnel - Replace linear and sequential determination of military and family member attitudes, beliefs, concerns leading to policy decisions - A MANPRINT-like process is needed in systems development – currently atrophying
21st Century Problems		
- Mastering the rapid, incremental fielding of complex, fragile information systems - Managing the transition from an Industrial Age military to an Information Age force - Continuous learning, remote, embedded, new psychological learning model	- Missions that demand more "experienced" capable leaders at a younger age - Integration and synchronization skills at lower levels - Achieving cohesion for dispersed, technically diverse and dynamic units - Achieving cohesion for culturally diverse units	- Soldiers will have to be information-enabled for all aspects of their life in the Army - Radical deployment demands will impact soldiers' lives in new ways - Retention of "competent" soldiers across the span of a career as the Army becomes more technical - Parameters of "multifunctionalism" in future Army

Table 2. Challenges for Training, Leader Development and Soldier Support.

4.2.5 Advanced Distributed Learning Technology Assessment

DoD is greatly interested in achieving the capability to train and educate its military and civilian workforce, anytime and anywhere it is required, with systems tailored to individual needs. Today's tremendous advances in information technology put us on the verge of an enabling environment for Advanced Distributed Learning (ADL). In the end-state, ADL hardware and software must have the characteristics of accessibility, interoperability, durability, reusability and cost effectiveness.

A recent DUSD(S&T) sponsored front-end assessment and workshop identified key components for a research agenda to achieve a robust, national ADL capability by the end of the decade. Participants represented a cross-section from the Services, government, industry and academia. These people were recognized experts in areas that included education, training, curriculum development, software engineering, hardware engineering, educational research, cognitive and behavioral science. The four key research areas that were identified as necessary to enable the ADL vision of a readily available instructional environment to support anytime, anyplace, anyone, anything learning were:

- Intelligent Computer-Aided Instruction: Cognitive Theory; Assessment; Collaborative, Group and Team Learning; Intelligent Tutoring; and Human Computer Interface.
- Authoring Tools.
- Distributed Simulations.
- Dynamic Learning Management.

4.2.6 NRAC Training Technology Study

The Navy Research Advisory Committee (NRAC) conducted a study in 1999 examining ways for the Navy training system to take better advantage of current training technologies, and

recommended areas where investment in training technology research would provide the greatest leverage for future Navy training requirements. The Committee observed that DoD is a unique national resource for training R&D, and that little training R&D is done in industry. Recommendations to the Director of Naval Training regarding essential S&T included:

- Develop a comprehensive initiative on measures of training effectiveness, including products and outcomes
- Sustain human systems R&D, including Cognitive Sciences, Decision Support Systems, and Human-Centered Design
- Emphasize embedding of training systems in operational systems
- Endorse initiatives to strengthen

4.2.7 NATO Study of Land Operations in the Year 2020

In 1999 the NATO Research and Technology Organization (RTO) conducted a study of Land Operations in the year 2020. A significant observation, relevant to behavioral, cognitive and social science research, was that situational awareness will be a key variable, not only from the standpoint of perceiving and understanding the physical reality of the battlespace, but also understanding the situation as the opponent sees it. The RTO report recognized the danger that the volume of raw data generated by future digital systems might swamp commanders with information. The challenge will be to filter and manage the data such that it provides pertinent, easy to use information that is tailored to the level of command. In addition, the report states that staff structures will have to be adapted and military personnel, at all levels, are likely to need new skills and be recruited and trained accordingly. All of this is no small challenge, and the behavioral, cognitive and social sciences are crucial enabling disciplines.

5. Productivity and Impact Assessment

The assessment of military behavioral, cognitive and social science research productivity and impact was approached in two ways. The first focused primarily on reviewing the contributions or problem-solving record of military supported basic research that has had far-reaching impact and which has transitioned into multiple applications. The second was through the formal Basic Research TARA and the Human Systems TARA review processes for 2000.

5.1 Behavioral, Cognitive & Social Science Contributions to Military Problem-Solving

Contributions to military problem solving from behavioral, cognitive and social science research lie mainly in three areas: group behavior, individual behavior, and human-machine interfacing. In this section, each area of contribution will be treated in turn. What follows is not intended to be a comprehensive survey; rather, it provides a sampling from each area intended to illustrate the classes of problems for which behavioral, cognitive and social science research have given answers.

5.1.1 Group Behavior

5.1.1.1 Teamwork

We have a saying in the military: "Train as you fight." An important corollary is that wars are fought not by individuals but by groups. The members of a fighting force are parts of a complex system whose components must work in concert to achieve success. We train together those who will fight together in order to build teams of people who know how to work with each other. Simply throwing together a group of people and assuming their proximity will result in teamwork does not work. In each potential team, there is variation in skill levels and abilities. A strong team will have each of its members performing the tasks to which each is best suited. It will have agreed-on methods of communication, both within the group and between the group and other components of the system.

Continuing behavioral, cognitive and social science research provides the evolving knowledge base we need to keep team performance at peak levels as demands on the team change. Many knowledge streams feed into the methods that are employed to build and maintain high performance. Our scientists have studied the nature of judgment formation and decision making, group dynamics, cultural and gender integration, the evolution of communication modes, the nature of leadership, the interaction of leadership style and group performance, aptitude testing, training techniques, and placement and assessment techniques-- all in order to find ways to build ever stronger, ever-better-performing teams.

It would be natural to think that eventually all the answers would be found and that team performance would reach a peak and remain at that level. That is not so for many reasons that may be summarized by saying that the conflicts in which we become involved change and the means for addressing new demands must be developed.

Two brigades charging each other across a field is no longer the modal conflict. Now some of our soldiers are peacekeepers who must make militarily and politically delicate judgments when under attack. Most of our experience in peacekeeping has occurred since the end of the Cold War. Often we are part of a multinational force sometimes under our command, sometimes not. Our fighting units contain broad ethnic and racial diversity. Most units contain women as well as men. We are

at the leading edge of cyber warfare, a form of conflict that will require new kinds of teams, new skills, new modes of communication. We are working toward a form of warfare in which the tasks performed by each of the Services will be integrated to a degree that has been, heretofore, unprecedented. The point is that needs are changing continually. Yesterday's research resulted in today's methods of addressing current needs. Today's research, if adequately supported, will result in the means to address the requirements of tomorrow's defense teams.

5.1.1.2 Judgment and Decision Making

Among the areas in which significant scientific advances in support of military needs have been made is that of judgment and decision-making. Thirty years ago, there was no science of judgment and decision-making. Military support largely created this scientific field. It did so because improving our fighting forces required us to understand how to make more efficacious judgments and decisions. What information do we gather naturally in making a decision? What information ought we to gather to make a good decision? How should knowledge be shared to optimize a decision? How do we identify and weigh choices? How much information is enough information? How are decisions made under extreme stress? What improves the quality of such decisions?

These are a few of the thousands of questions scientists studying judgment and decision making have addressed in the effort to formulate means for helping military personnel improve judgment and decision making skills. The results of the research are seen in the ways today's military personnel are trained, in the kinds and quantities of information made available to decision makers, and even in the ways information is allowed to travel in a chain of command. This is a young science. Its contributions already have changed the Services. This is also an inconspicuous science in that its product is better soldiers, not new and attention-grabbing hardware. Its discoveries are incremental, not splashy. But the importance of this science to the country's defense should not be underestimated for its inconspicuousness. In the end, the efficacy of our national defense boils down to the quality of the decisions made by our military personnel.

5.1.1.3 Leadership

Capable leaders and decision makers are crucial to the armed forces. Their decisions save and lose lives, win and lose wars, preserve or destroy peace. Before military funding directed scientists toward the study of leadership, it appeared a leader was a leader was a leader. No longer. Thanks to research, we know that there are many constellations of leadership skills, and there are many contexts in which leadership is needed. The value that has been added by the research is that we can be very sophisticated in matching the skill constellation of particular leaders with the contexts in which their skills are most appropriate. For example, speed of quality decision-making is a critical leadership variable. The rapid decision maker can make good judgments on the basis of a meager amount of critical information. This is the leader we want at the head of a unit caught in a brutal firefight. On the other hand, there are contemplative leaders who require large amounts of complex information before reaching a decision, and who will not be rushed into a decision. We want such leaders defining goals, planning strategies, identifying objectives. We are more precise in our leadership choices and placements now because our funding has fostered a science of leadership that is telling us how to best prepare and employ leaders.

5.1.1.4 Team Dynamics/Group Cohesion

Who comes into the armed forces in a given time period depends on such things as the state of the economy, political events in the world, and even the level of patriotic feeling in the population. Whoever enters the military, it remains our job to see that they become "the best that they can be," to paraphrase the Army slogan. That is an astonishingly challenging task. Consider that the educational range of recruits varies from less than a high school education to college graduates.

Both men and women are welcomed from a broad spectrum of racial, ethnic, and cultural backgrounds. The challenge is to take people whose differences are extreme and turn them into members of smoothly, effectively functioning units capable of working in concert with other units comprised of equally dissimilar members.

The research that goes into meeting that challenge is extensive. It begins with ongoing work to develop assessment instruments that tell us in detail what skills and abilities each recruit possesses and what level of development is presented for each skill and ability. It progresses to research on efficient, effective training. The overriding question to be answered is, "How do you take a novice in a given task area, and train that person to mastery or even to expert performance at reasonable cost and in minimal time?" The research needs to be ongoing because the tasks to be trained at least evolve and often change radically over time.

Then there is research on placement. To get the most out of our personnel, we must consider the social context in which they will work. At the simplest level, we want the right skill mix for optimum performance of a unit's functions. But assuring that people with the proper training to complement each other's skills is only a fraction of what needs to be done. Cultural, gender, and even language differences must also be understood sufficiently to assure not only that the unit members have the technical skills to work together, but also that they understand each other well enough to know how to work together.

DoD as a large organization is continually challenged to ensure that gender, racial, and sexual preference discrimination does not exist. The factual record is that we have fallen short at times. It is our intention to conduct the appropriate research to find ways to build units whose members are diverse and yet are able to work together harmoniously.

Thanks to research we have already supported, we often fulfill that intention. But we know that there is yet much that we must learn. We know from our survey research, for example, that feelings among enlistees on these differences are deeply embedded. In all likelihood, they pre-date enlistment. But pockets of similar discriminatory beliefs within a unit can lead to cliques, to differential treatment of one group by another, and sometimes even to violence--as it does in the civilian society from which our enlistees come. The challenge, in a sense, is to overcome in the Services the passionate beliefs about differences that are part of American society.

To that end, we have supported research on cross-cultural communication in the workplace. Even though we use words and gestures in our everyday communication that we think we all understand in common, our research has demonstrated that this is not the case. We are working at ways to help our personnel understand the meaning of communications trans-culturally. Cultural differences in meaning aside, we also deal with language differences among enlistees. We support research on the nature of language learning, both to address this problem and to prepare ourselves for the increasingly common situation in which our forces work with forces of non-English speaking nations. The socio-cultural research also does double duty in this regard.

We are equally concerned about minimizing any adverse effects of gender differences. Just as we have studied ways to better fit people to tasks, we are also studying ways to fit tasks to people. One thing that our research has told us, for example, is that with minor modifications in tasks, virtually every job in the military can be performed well by men or by women. This has been a concern because career paths are influenced by work assignments and experience. The research tells us that there are few physical impediments that cannot be overcome among tasks required of people in uniform. Diversity is a complex area for research to tackle. Our goal in funding the research and its applications is more effective socio-cultural integration of the Services.

5.1.2 Individual Behavior

While the focus of personnel-related behavioral, cognitive and social science research supported by the Services is on producing consistently high quality performance by and among units, there are a number of issues having to do with individual behavior that are also studied because of their relation to human performance. Perhaps the two most prominent areas of individual behavior of interest in the military context have to do with capabilities and limitations in perception and in cognition.

5.1.2.1 Perception Research

The human senses are calibrated to the world in which humans normally live. Those senses do their jobs within what are normally reasonable boundaries. Combat stretches the needed boundaries of the senses. Behavioral research supported by the Services is aimed at understanding the natural limits of the senses and at finding ways to exceed those limits. The three major forms the research takes address devices to augment sensory capabilities, protection of sensory capabilities from damage, and fundamental understanding of the senses.

5.1.2.1.1 Augmenting Sensory Capabilities

We want to "hear" quiet enemy submarines. We want to fire weapons with great accuracy while moving faster than the speed of sound. We want to "see" in the dark and over hills. We want to be unaffected by chemical and biological agents, fatigue, and extremes of temperature. And we have many other wants that stretch the limits of the human senses. Fulfilling these wants has put behavioral and social scientists in interdisciplinary teams with physicists, engineers, chemists, and a variety of other scientists.

One of the great contributions of behavioral science to military science has been signal detection theory, a mathematical means for finding needles in haystacks. In the ocean, one finds a cacophony of sounds. Against the noise of the ocean, the sound of a submarine, particularly a submarine with advanced quieting technology, would be invisible were it not for signal detection theory which offers a statistical method for judging the likelihood that a particular sound is the signal of a submarine and not the noise of the ocean. The same technique can be applied to distinguishing enemy tanks from the foliage that disguises them, or dangerous fatigue in the fuselages of military aircraft. In the civilian sector, this technique developed to meet military needs is used to increase the accuracy of diagnoses of breast cancer from mammograms, and of HIV from serum samples. Here is a case where research has extended the range of vision as well as hearing to the advantage of both the military and civilian sectors.

5.1.2.1.2 Protecting Sensory Capabilities from Damage

Recent experience suggests that future conflicts will require rapid mobilization of troops to remote parts of the world. Characteristic of such long-haul transport of troops is extreme fatigue. The pilots who must transport the troops have been, and will be, required to fly for long periods of time. The troops will be rushed to preparedness and then confined to their transports for many hours. And once in battle, extreme fatigue often becomes the rule rather than the exception. Our research shows alarming drop-offs in mental and physical functionality with increasing fatigue. Moreover, the recovery rate for cognition and judgment are much longer than is apparent from simple observation.

We have turned research resources toward trying to understand how to counteract what amounts to a near shutdown of cognitive and sensory systems with increasing fatigue. Our researchers have studied circadian rhythm, the internal clock by which our bodies time many bodily activities

including alertness. They are studying interventions to minimize the effects of fatigue. Both military and civilian pilots have profited from this research. While it may seem injudicious to a layperson that on long hauls it is becoming more and more common for crewmembers to work and sleep in shifts, the reality is that this intervention is making for much safer flight over long distances.

Research is also underway on ways to alter circadian rhythms so that they coincide more rapidly with the time zone in which troops must perform. Controlling light and diet can now facilitate such alterations. But deepening understanding of the bodily mechanisms that trigger the undesirable effects of fatigue may lead to greater ability to "turn on" qualities such as alertness and cognitive acuity when those qualities are most needed. Again, though some of this research is now at the basic level, the developments that will eventually flow from the research will have great benefit for the military as well as the civilian sectors.

5.1.2.1.3 Perceptual distortions

Perceptual distortions have been at the root of tragic flight accidents. One class of incidents had to do with the use of night-vision goggles by pilots. In several instances, pilots wearing these devices plowed into the earth as they attempted to land. Malfunction of the equipment was ruled out as a cause, and it seemed there was no good explanation for the accidents until scientists began to wonder how the human visual system actually processes what is being presented to it through night vision goggles. Their research revealed that the goggles presented insufficient distance cues to pilots. The unaided visual system functioning in daylight uses cues such as foreshortening of objects as they recede into the distance to judge how close or far an object is from the viewer. Night vision goggles amplify the heat radiated by objects to form images. There is little perceptual information generated about differences in terrain by this technology. The result is that pilots "see" the approaching terrain as farther away than it actually is. When they think they still have some distance between their aircraft and the ground, they are already crashing into the ground. Alteration of night vision goggles for pilots to give better distance cues has compensated for the perceptual distortion and eliminated it as a cause of crashes during night landings.

5.1.2.1.4 Perceptual Overload

The capability of technology to produce useful information far outstrips the ability of human sensory systems to use that information well. At least as far back as the Vietnam conflict, it was known that pilots routinely turned off many of the information output devices on their planes and flew by instinct instead. They found it too burdensome to split their concentration between the data being fed to them by their instruments and the information they gathered simply by looking out the cockpit window. A classic psychological study done decades ago established that a human being can hold about seven items in working memory. Modern sensing devices can provide pilots, air traffic controllers, tank operators, munitions specialists, and other operators of high technology devices with many times more than seven informational items at once.

In partnership with the National Aeronautic and Space Administration and the Federal Aviation Administration, we have directed behavioral research dollars at understanding what information, what sequence of information, what speed of information presentation, and how much information is optimal to present visually, aurally, and tactilely to operators of high technology equipment. A great deal of basic and applied knowledge has flowed from this research. We have learned that the human visual system is an averaging system. That is, what we perceive is not precisely what is out there. We see better in dim light than we ought to see, for example, because the visual system has some limited capability to amplify input.

One application of this understanding has been in saving cost on development of training simulators and virtual reality devices. The fidelity that is needed to convince the visual system, and for that matter, the tactile and auditory systems, that what they are sensing is true to reality is not nearly as great as we are capable of producing technically. Thus, we can decrease the fidelity of a visual display in a flight simulator without degrading the apparent reality of the simulation. We can compress aural information because the ear and brain will fill in what is missing. And virtual reality devices need not convey every nuance of movement to give the operator of the device the tactile cues necessary to perform remote operations successfully.

An area of exploration still underway has to do with how to arrange and sequence information in the visual field so that it can be used accurately and comfortably. One line of this research is directed at symbols and meaning. The question is, what symbols can be used to convey information in an unambiguous way? This line of research has particular application in the development of "heads-up" displays, that is, in the projection of information on the windshield of an aircraft, or on the screen of virtual reality goggles, or on a gunner's face shield.

The research is demonstrating that everything counts in enhancing usability: where the symbols are placed, the distinctiveness or distinguishability of one symbol from another, how much choice the user has in choosing the information that will be displayed.

Also of concern is the finding that the human ability to switch attention from foreground to background is limited. The implication is that, if not engineered properly, heads-up displays, which are meant to aid operators by freeing them from having to look away from the terrain in order to check instruments, could cause as many problems as they solve. Here is an instance where basic and applied research in perception is essential to the proper engineering of high technology devices. Without the behavioral research, we run the risk of unwittingly engineering danger into devices intended to enhance safety.

5.1.2.1.5 Perceptual Inabilities

We lack some perceptual abilities that we can overcome through research. An intriguing instance of such research has to do with something called "chaos theory." Most mathematics, and certainly most behavioral mathematics, are built on the assumption of an orderly world: If A occurs, we can expect B to follow. You push me hard enough and I will fall down, for example. The mathematics that describes such orderly sequences is called linear mathematics. But some things in the world appear to be chaotic, to have no order. Nonlinear mathematics are being developed to extract some order from apparently unordered phenomena. Turbulence was the earliest "chaotic" phenomenon to which chaos theory was applied. For example, hydraulic engineers wanted to know how to construct more efficient fluid-carrying systems. The friction caused by turbulence in pipes is a major impediment to the efficient flow of fluids. Chaos theory was applied to fluid turbulence in order to find ways to make pipes that carry fluids more efficiently. Chaos theory has been applied to jet engine exhaust to find ways to make jets quieter and more efficient.

This is very basic research. Its practical applications to physical turbulence are closer than its practical applications to behavioral complexity. The possibility it holds for military purposes, however, is that it could greatly enhance our ability to anticipate what our opponents might do, when they might do it, and even the strength they might put into their action. If we can understand the boundaries within which our opponents behave and the boundaries of other phenomena, such as our own behavior, that could trigger opponent action, then we will have an advantage over our opponents in battle and a valuable tool in diplomacy as well.

5.1.2.2 Cognition

Some aspects of research on cognition have already been mentioned. Military support has enabled much of the development of cognitive science, and the return on that investment has been rich and has extended across a great many military needs. More will be said about the applications of cognitive research to the design or improvement of human-machine interfaces and to the engineering of smart machines in following sections. Here, research on cognitive capacities and on training for complex tasks will be highlighted.

5.1.2.2.1 Cognitive Capacities

Military funding helped lead to one of the most important theories of cognition of the past twenty years. It has been a tenet of folk wisdom for thousands of years that the right way to learn is to begin with the simple and move to the complex. One learns to count, then to add and subtract, then to multiply, then to divide, for example. The connectivist theory of cognition calls that concept into question. A simple explanation of the theory might be stated this way: Knowledge is only partly about the number of discrete pieces of information one holds in one's head. Equally important is the number of relations or connections the brain can make among those pieces of information. The counter-intuitive implication of the theory is that better learning occurs when more information is presented than when less information is presented. Why? Because the more ways a brain can store and interconnect the information it possesses, the more pathways the brain has for accessing that information and the more ways several pieces of information may be linked in any attempt to solve problems.

For human-related work, connectivist theory has guided further basic research to determine how quickly large volumes of information can be reliably committed to memory and accurately retrieved. That basic research suggests that while working memory can handle about seven items at a time, hundreds of items can be committed to long-term memory in a short amount of time by compressing learning trial times. While it may still take thousands of trials to learn those hundreds of items accurately, individual item presentation times are reduced to milliseconds such that the hundreds of items can be learned in a few hours rather than a few days or weeks.

5.1.2.2.2 Training for Complex Tasks

There are at least two major reasons this research is of significance for military application to humans. Highly technical training is costly to administer in part because it takes large amounts of time to convert complete novices into even advanced novices. And we would have a much stronger human resource in the field if training were capable of converting novices into true experts.

A cognitive change in problem solving strategy occurs when a person moves from being an advanced novice to being an expert. Even gifted novices are serial processors. They solve problems by moving from step A to step B, and so on. True experts process information systemically. If certain conditions are satisfied at step A, the expert knows he or she can skip steps B through F, say, because their outcomes are conditioned on the status of the system encountered at step A. The expert is both efficient and fast at his or her task. What changes a novice into an expert? Practice. More practice than it is usually possible to give in a training environment. The implication is that soldiers are placed in their specialties after training periods that have not brought them to the performance level of experts. They generally pick up the rest of that training on the job. We would like training to be so effective that personnel emerge from it as experts because the more highly trained they are, the better they will do their jobs.

Connectivist cognitive theory provides a means to accomplish that end. Though not yet applied in all training settings, connectivist training routines have raised the performance level and cut the training time for technicians who must trouble-shoot problems in the highly complex printed circuitry of fighter planes. The expertise of air traffic controllers has received a similar boost from training based on connectivist theory. And one motivation for development of computer-based virtual reality training environments is that more trainees can experience the equivalent of extensive "hands-on" practice than is now possible either with expensive simulators, which are in short supply, or with real equipment, which may also not be easily accessible for training purposes. The virtual reality training modules that are emerging have the added advantage of being able to track the progress of each trainee individually and to provide extra practice tailored to the particular needs of the individual trainee.

We understand that not every training setting will lend itself to application of connectivist theory. But the notion contained in the theory that practice builds up connections among informational items that then increase the individual's problem solving power is being applied beyond the initial training setting through embedded training. This is a research and development effort aimed at building training software into the equipment used by military personnel in the field. For example, much of a sailor's time at sea is down time. It is waiting while the ship sails to the place it is needed. By embedding interconnected training software in the devices aboard a fleet of ships, it is possible to simulate a variety of battle training scenarios. This, in turn, permits sailors to convert down time to practice time so that their skills may reach expert levels before they must be employed in actual battle.

5.1.2.2.3 Better Machines

The theory has had implications not only for the way the military approaches training of complex tasks but also for the effort we are making to build machines that can think, and do so very rapidly. Parallel distributed processing, the application of connectivism to artificial intelligence, has greatly increased the processing possibilities for military as well as civilian computers. Such circuitry allows a computer to store and perform operations on parts of a complex problem at the same time, or in parallel. The limitation of serial processors, the computers most of us use everyday, is that the steps in a problem solution can be sequenced no faster than the speed of light. Amazingly enough, that is too slow for such things as provision of near-real-time data to soldiers on the ground from satellites overhead, or for a host of equally processing-speed hungry military needs. When the parts of a problem, or multi-step operation, can be carried out at the same time rather than serially, limitations on speed of processing for a single sub-operation become much less important to the overall speed of computing.

Connectivism provides the theoretical structure for accomplishing that end and, thus, lies at the root of a significant portion of the work in informatics being supported by the Services today. Three areas will be highlighted here: neural networks, robotics, and voice-recognition technology.

5.1.2.2.4 Neural Networks

Despite rapid advances in computer development, it remains the case that the human brain is the most powerful computer we have. In addition to its massively parallel circuitry, another of its great advantages over most computers is that it learns. It literally makes itself better with experience. That is a highly desirable quality to be able to place in a variety of devices the Services want to build -- from satellites that improve their surveillance capabilities over time, to sensors that learn to be more sensitive with experience, to robots that understand and correct their errors.

Accomplishing those long-range objectives depends on understanding how the brain is constructed and how that structure allows it to gather, code, interconnect, correct, modify and use information. As we have gained in our understanding of these things, we have begun to construct circuitry that imitates the human brain. The research we are supporting in this area is called neural network research. It is a highly interdisciplinary endeavor employing cognitive scientists, neuroscientists, linguists, software and hardware specialists, and other experts.

Much of the research is still basic. But some applications have already emerged. Circuitry that can learn, for example, is aiding anti-terrorism efforts. Plastic explosives are a weapon of choice by terrorists, and it has become essential that we improve our ability to detect them. When devices to detect plastic explosives hidden in luggage were first being developed, it was discovered that the task was daunting. The machines were not accurate. Then circuitry that could learn was designed into the devices, and the machines were "taught" to recognize plastic explosives by presenting thousands of training trials to them. With practice, these machines became adept at detecting the explosives. Compared to what we hope to accomplish as the scientists we support make breakthroughs in their understanding of human cognition and neural networks, this learning circuitry is primitive.

5.1.2.2.5 Robotics

It is in robotics that we expect the major payoffs from support of this research to occur. We have been moving over the past two decades toward making ourselves capable of exercising decisive control of conflict situations with minimal, or even no, loss of life among our personnel. Improved robotics are key to making further strides. And improved learning circuitry is one of several keys to improved robotics. Our plan is to mate sophisticated sensors, smart circuitry, and nanotechnology to produce devices that can fulfill as many tasks now performed by personnel as possible. In the future, we will employ people only in the functions that cannot possibly be performed by robotic devices. Many of those essentially human functions will, in all likelihood, be performed far from the battlefield by personnel controlling devices remotely. Navy investment in this research is particularly noteworthy. Its active program of research, development, testing and evaluation is already resulting in declines in the number of crewmembers needed to operate many of the ships in the fleet.

5.1.2.2.6 Voice-Recognition Technology

Computer users now think nothing of going to their local computer store and buying software that allows them to talk to their computers rather than input information by means of a keyboard. Few of those users know what a monumentally difficult undertaking it was to create voice-recognition technology. It is a breakthrough technology developed largely through defense funding over a period of nearly forty years. For the Services, this technology has been desirable because it has many applications. The complexity of tasks personnel may perform is enhanced by adding the voice as a device control mode. Remote control of devices is simplified. Security is enhanced. Access is controlled. The utility of certain sensors is increased. Automatic translation of spoken language becomes possible.

When the quest to develop this capability began, scientists were unsure that it was even possible. Psychoacousticians knew not only that each voice is unique in its vibratory pattern, but also a single person saying the same thing twice can show considerable variation in the waveform pattern the vibrations form on an oscilloscope. Linguists knew that individual speakers vary in the meaning they attach to given words and that phrases that sound alike may have different meanings. When the basic research began in this area in the 1950s, there was no computer in the world powerful enough to recognize the meaning of a single phrase spoken by a single speaker, even if

there had been theory to support how it might be done. Experts in psychology, philosophy, linguistics, acoustics, programming, electronics, and a host of other specialties labored over decades advancing fundamental understanding in their own sciences as they chipped away at this difficult applied problem. At one point, the obstacles to making this technology appeared so overwhelming that the Defense Advanced Research Projects Agency gave up and withdrew funding, only to take up the quest again when developments in key sciences brought renewed hope.

There is no industry that would have invested forty years of research or enlisted the expertise of so many disciplines to cultivate the basic knowledge that led to the applied research on prototypes that finally resulted in the ability of a computer to recognize and respond correctly to millions of very different human voices. It took the long-range commitment of the Defense Department to creating this device for its own needs to make it possible.

5.1.3 Human-Machine Interface

It was pointed out earlier that we have the technical capability to provide much more help to human users of equipment than any human can use. Progressively it will become the case that military personnel will be assigned to critical tasks, those that cannot be done through robotics, automation, or remote sensing. They will be cognitively demanding tasks requiring judgment, training, and the right assistive devices. It is ergonomics and human factors scientists to whom we look to assure that these devices truly assist rather than hinder or even endanger human users.

Several examples of this application of behavioral, cognitive and social science research have been mentioned, including unambiguous symbology, improved night vision goggles, and visual, tactile, and auditory cueing on simulators and in virtual reality environments that are commensurate with human sensory acuity. Common to the examples of this research is that the applications are hardly noticeable. When the researchers in partnership with the engineers have done their jobs well, the interface between operator and machine appears seamless. The device is operated easily. Controls are effortlessly accessible, and located just where one might think they should be located. One control is not easy to mix up with another. Human and machine fit together like a hand in a glove. Of course the ease built into machines is far from easy to build in. The ease of use seems a natural part of the engineering until a similar device without benefit of human factors engineering is compared to it. Research to make military devices "user friendly" makes sense from two important standpoints: safety and ease of use.

5.1.3.1 Safety

When an aircraft is secured prior to maintenance, a number of pins must be inserted in a variety of fixtures around the plane to protect parts that could be damaged and to protect maintenance personnel from accidentally activating devices that could injure them. To assure both, all the pins must be inserted properly. Pin sizes and shapes are standardized to the extent possible to reduce error. Where standardization is not possible, signage highlights the fixtures that differ from the others. The pins themselves are arranged for storage on a series of coded hooks so that the maintenance mechanic can be sure that all the pins have been placed in their fixtures and that the proper pin has been inserted in the proper fixture. Mistakes in this preparatory procedure can lead to the disabling of an aircraft or to the injury of a maintenance engineer. Human factors engineering of the preparatory process helps assure that neither occurs. There are many such instances of subtle, and seemingly mundane, attention to ergonomics and human factors that afford safety to the users of what are inherently dangerous devices.

5.1.3.2 Ease of Use

Human factors and ergonomics research are aimed at understanding how people use devices, and at understanding what human anatomy requires of devices to make them useful in ways that do not cause undue stress, fatigue, or unnatural displacement of the body. Ease of use has a significant impact on how long personnel can remain productively at a task, how soon they can return to that task, and how successfully and efficiently the task can be performed.

We have to ask a great deal of personnel involved in violent conflict. The environment is stressful by nature. We certainly do not want the equipment that is meant to help personnel perform their tasks well to be itself an impediment to performance of the task. Consider the control stick on a fighter plane. At a pilot's fingertips is the power to control the firepower of the plane and the plane itself. Such accessibility is very efficient. But what if that same efficiency made it easy to mistakenly fire a missile when the pilot meant to fire the cannon or eject when he meant to drop a bomb? The capability to do several of those things are within an inch or two of each other on the control stick. Yet such mistakes are essentially non-existent. Why? The shape, the feel, the placement, the color of each control was human factors engineered to help the pilot perform his or her task flawlessly. The need to incorporate behavioral research into device design is ongoing.

5.2 TARA Assessments

5.2.1 Basic Research in the Cognitive and Neural Science Discipline

5.2.1.1 General Assessment Criteria for Basic Research

- Research Quality – How does quality compare with research outside of DoD?
- Defense Relevance – Will this research meet DoD's long-term needs?
- Coordination – How well is this research coordinated with related relevant research efforts from which it might benefit, both in & out of DoD?
- Investment Strategy – Is it ready for transition from research to development? Are there additional emerging opportunities? Are the topic areas balanced considering importance to the DoD?
- Critical Mass – Is the funding level appropriate, given the program objectives? If not, from where should the funds be transferred?

5.2.1.2 Findings Regarding Cognitive and Neural Science

The Basic Research TARA panel evaluated the Cognitive and Neural Science program as an overall "Green." That is, the program was assessed as progressing well towards achieving its goals. The panel also noted that the program is well coordinated, represents a good investment strategy, and addresses issues that are clearly related to DoD needs.

5.2.2 Human Systems Technology Area

5.2.2.1 General Assessment Criteria

- Does the program address relevant warfighter needs?
- Is the technology state-of-the-art?
- Does the level of effort conform to defense priorities?
- Are timelines reasonable? Do they meet warfighter needs?
- Do efforts have clearly defined, quantified exit criteria?
- Are there unrealized opportunities for synergism with other technology areas, or with non-Defense entities?

- Are funds distributed appropriately across subareas?
- Are resources adequate to reach objectives?
- Do the DTOs contribute significantly to subarea goals?

5.2.2.2 Design Integration and Supportability Subarea

Overall, this subarea was found to be progressing satisfactorily. Additional work on metrics would strengthen its contribution. Particular strengths noted by the panel included: a) Good emphasis on cost-effectiveness; b) Strong user involvement and understanding of operational requirements; c) Good understanding of international efforts; and d) Data on human behavior in operational environments are essential for many purposes.

5.2.2.3 Information Display and Performance Enhancement Subarea

The ID&PE subarea was evaluated as progressing satisfactorily. Particular strengths that were noted by the panel included: a) Strong user involvement and understanding of operational requirements; b) Good emphasis on field evaluations; and c) Data on human behavior and cognition in operational environments are essential for many purposes.

5.2.2.4 Personnel Performance and Training Subarea

The panel graded the PP&T subarea as progressing satisfactorily toward its goals. The panel observed that there is high warfighting and cost-effectiveness payoff and future potential in this subarea, and that accomplishment in this subarea position DoD and the nation to capitalize on rapid advances in information technologies and understanding of human cognition. The panel also noted that this is a very dynamic area. It requires increased emphasis on documenting methodologies employed and lessons-learned to better leverage S&T beyond specific applications. The panel encouraged a worker-level Technical Advisory Group (TAG) in cognitive modeling, personnel, performance and training be established. The TAG would be charged with cross-fertilization of lessons-learned, findings and technologies (e.g., the well-accepted Human Factors Engineering TAG).

6. Funding for Behavioral, Cognitive and Social Science Research

In this chapter we will identify the funding for behavioral, cognitive and social science research across the military S&T base, and describe general trends in Armed Services' S&T support within and between the Services and in the context of overall Defense and Service spending.

6.1 S&T Funding Relative to the Defense Military Budget

The Defense military budget for FY00 is 267.8 billion dollars. It includes 37.6 billion for RDT&E. Of the RDT&E funding, 7.8 billion is applied to Defense S&T. As shown in Figure 4, less than two percent of each of the Services' budgets is applied to S&T. The graphic puts into perspective the proportions of our current Services' budgets that are being put toward preparing for *future* warfighting capabilities and requirements, both known and unknown.

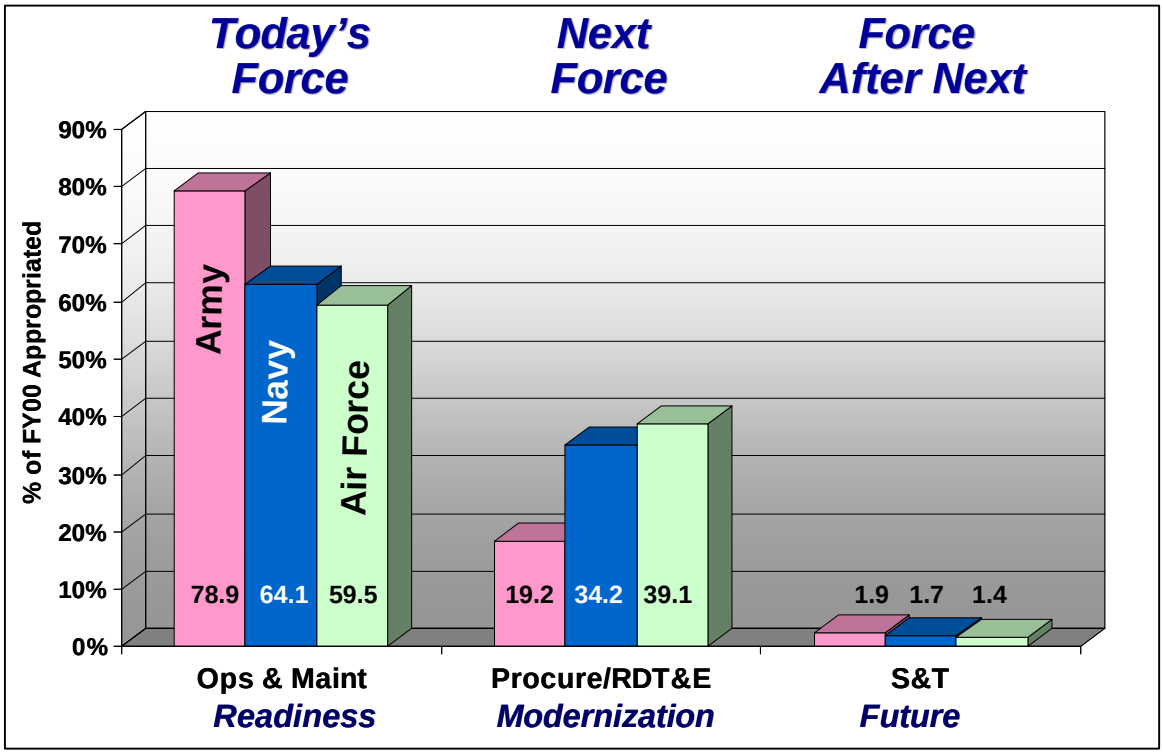

Figure 4. S&T as a Percentage of the DoD FY00 Military Budget.

With the ever-increasing pace of change in all aspects of life in the world today, simply maintaining America's S&T edge could arguably require a steady increase in overall S&T spending into the future. As shown in Table 3, from FY90 to FY05 the percentage of the DoD military budget going toward Service S&T is projected to decrease.

$ in Billions / FY01 Constant																
	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
DoD Military Budget	360.7	328.0	326.0	303.5	279.8	279.1	272.5	272.3	270.0	287.7	284.8	291.1	289.8	290.4	291.4	292.8
Service S&T (6.1 – 6.3)	5.0	5.1	4.6	5.5	4.4	4.8	4.2	4.2	4.2	4.3	4.9	4.0	3.9	3.9	3.9	3.9
S&T as % of DoD Military Bdgt	1.4%	1.5%	1.4%	1.8%	1.6%	1.7%	1.6%	1.5%	1.6%	1.5%	1.7%	1.4%	1.4%	1.4%	1.4%	1.3%

Table 3. Service S&T as a Percentage of the DoD Military Budget from FY90-FY05.

6.2 Service S&T Funding Stability

Figure 5 reveals the amounts and the trends of the individual Services' S&T relative to each other (the left *Y* axis) and to their combined total (the right *Y* axis). The data illustrates that the 1990s was a period of some volatility but that with the turn of the century stability in S&T funding has been achieved.

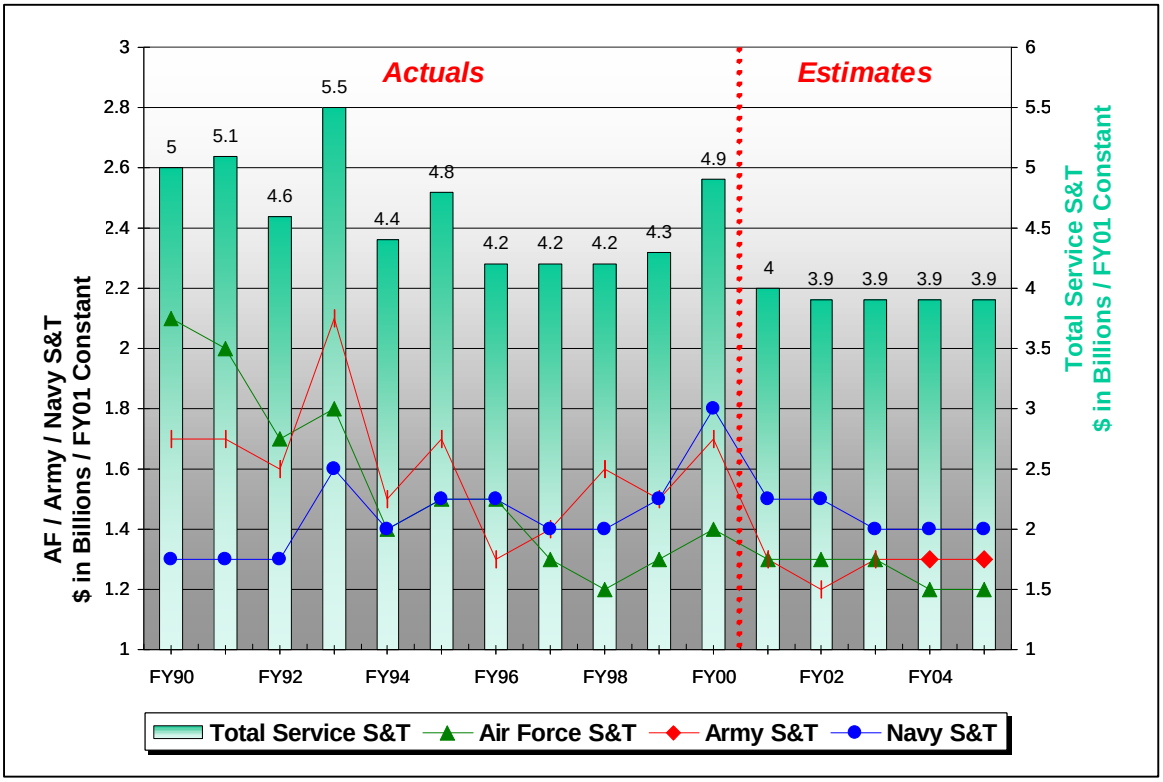

Figure 5. Service S&T (6.1-6.3) from FY90-FY05.

6.3 Behavioral, Cognitive and Social Science Research Funding

Figure 6 shows each Service's behavioral, cognitive and social science research funding as a percentage of its overall S&T budget for the period FY94-FY05. Air Force's investment in behavioral, cognitive and social science research is projected to stabilize at approximately 4.5 % of its overall S&T budget . The percent of Army investment in this area increases sharply in FY01

and then stabilizes relative to Army's total S&T investment. Navy investment in this area is projected to decrease slightly as a percentage of total Navy S&T over the period.

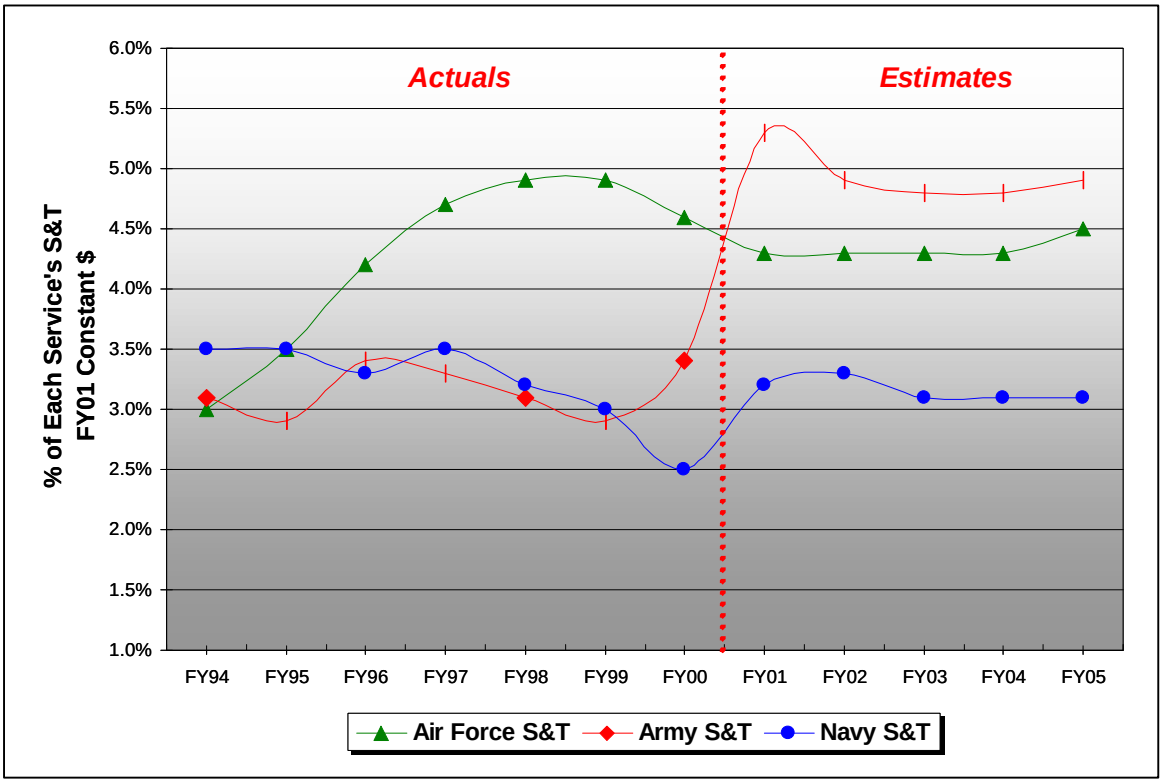

Figure 6. Behavioral, Cognitive & Social Science Research as a Percentage of Each Service's Total S&T for the Period FY94-FY05.

6.4 Behavioral, Cognitive and Social Science Research Funding Stability

Figure 7 shows the funding trends across the Services over the period FY94-FY05. (See Appendix B for numerical tables.) Air Force, while showing the greatest fluctuation among the Services over the period, appears overall to have a relatively level trend of investment when future year projections are included. Total Army investment increases significantly from FY00 on out. This increase appears due to additional investments in basic and applied research. Overall, Navy funding of behavioral, cognitive and social science research is projected to slowly decline. This appears within the Navy's applied research program in this area.

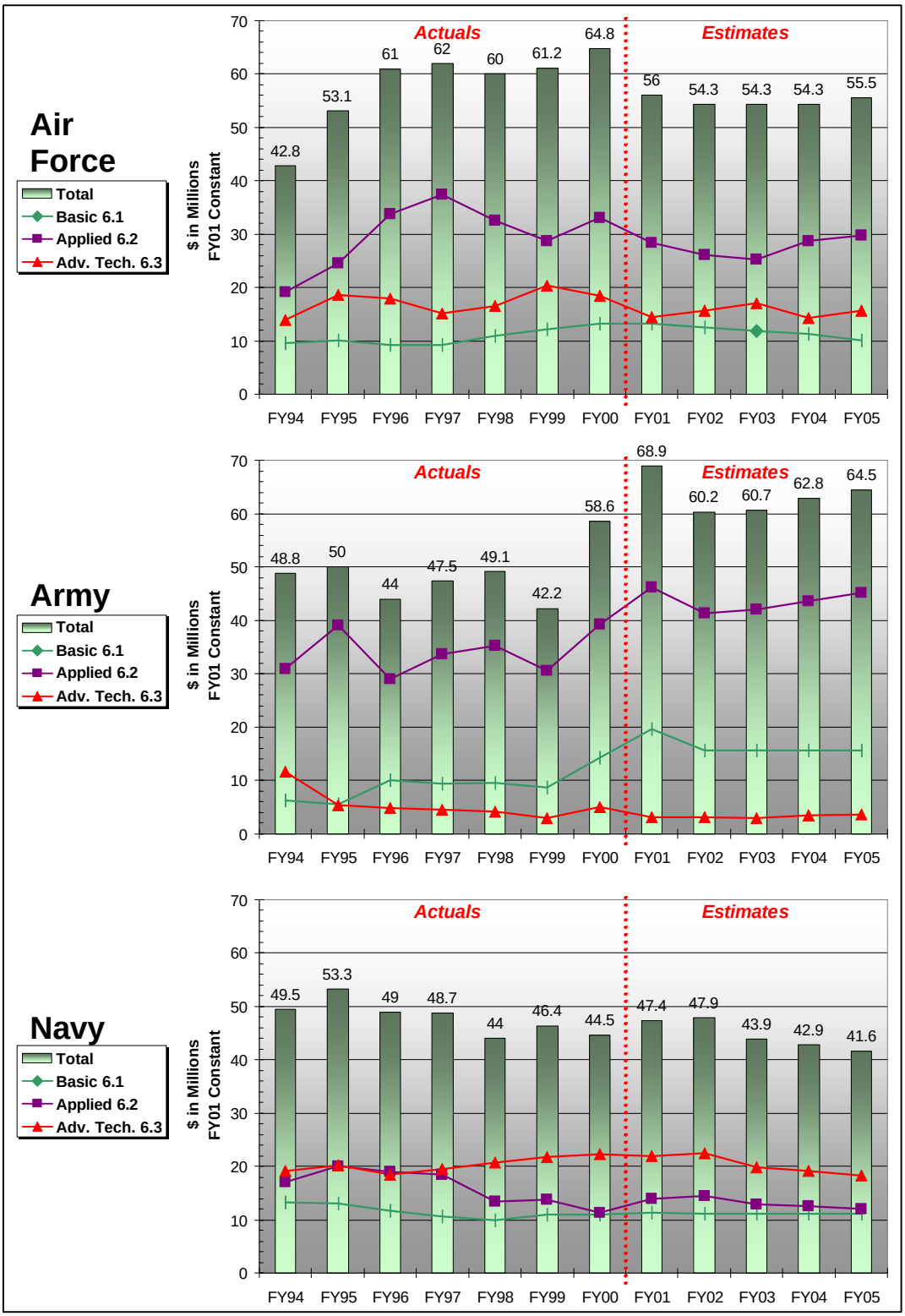

Figure 7. Behavioral, Cognitive and Social Science Funding from FY94-FY05.

7. Conclusions

This report identifies and highlights several key attributes of Defense S&T.

- The requirements for maintaining strong DoD support for behavioral, cognitive and social science research capability are compelling.
- This area of military research has historically been extremely productive. Return on investment is particularly high.
- In general, funding in this area has achieved stability.
- Behavioral, cognitive and social science research has produced, and will continue to produce, products with high operational impact.

Current Service plans and programs as represented in the FY01 President's Budget provide marginal, but adequate levels of funding in the area of behavioral, cognitive and social sciences research. The individual Services with their internal S&T planning processes, combined with the DoD TARA / Reliance structure and review processes provide adequate oversight and direction. Therefore, it is recommended that Congress continue to support the President's budget request for the science and technology program of the Department.

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Appendix A -
Senate Committee on Appropriations Report 106-53

DEPARTMENT OF DEFENSE APPROPRIATION BILL, 2000

Associated Bill -- S.1122

*Behavioral Researc*h.—The Committee is concerned with the continuing erosion of the Department's support for research on individual and group performance, leadership, communication, human-machine interfaces, and decision-making. The Committee encourages an evaluation on the application of behavioral, cognitive and social science research in the military, and the benefits of this research to military performance. The Committee directs the Department to provide a report by March 1, 2000, detailing this evaluation and including a plan with recommendations to strengthen this research across the military services.

Appendix B -
Funding Summary of Institutional Investments

Air Force Behavioral, Cognitive and Social Sciences Research Funding Summary

(Constant FY01 $ in Millions)[1]

PE/PROJ	PE/PROJ TITLE	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
0601102F	**Defense Research Sciences**												
2313	Human Performance	9.6	10.1	9.3	9.2	11.0	12.2	13.3	13.2	12.5	11.9	11.3	10.1
0602202F	**Human Effectiveness Applied Research**												
7184	Crew Technology	4.9	5.3	13.9	16.3	13.0	16.0	16.1	16.4	14.9	14.6	16.6	17.2
1121	Training Dev & Assessment Tech	4.0	3.6										
1123	Manpower, Personnel & Training Tech	7.1	12.9	19.9	21.3	19.5	12.7	16.9	12.0	11.4	10.7	12.2	12.4
7719	Force Acq & Distribution Tech	3.2	2.7										
	Total	19.2	24.5	33.8	37.5	32.5	28.7	33.0	28.3	26.2	25.3	28.8	29.7
0603227F	**Personnel, Training and Simulation Technology**												
2743	Advanced Training/Force Management	5.1	5.3	5.3	3.6	5.9	6.3	6.4	6.5	7.5	8.3	5.5	5.4
2922	Manpower and Force Management	1.5	1.6	1.6	1.2								
2949	Advanced Training Technology	2.4	2.2	2.3	1.5								
	Total	9.0	9.1	9.1	6.3	5.9	6.3	6.4	6.5	7.5	8.3	5.5	5.4
0603231F	**Crew Systems and Personnel Protection Technology**												
2829	Crew-Centered Cockpit Design	2.6	2.6	2.0	1.9								
2830	Crew Stations, Life Support, and Escape					1.3	1.9	2.4	2.7	3.1	3.7	3.7	3.7
3257	Helmet-Mounted Sensory Technologies	2.4	6.9	6.7	7.1	9.3	12.1	9.8	5.3	4.9	5.1	5.1	6.5
	Total	5.0	9.5	8.7	9.0	10.6	14.0	12.2	8.0	8.1	8.8	8.8	10.2
Air Force Accounts Roll-up		**FY94**	**FY95**	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**FY01**	**FY02**	**FY03**	**FY04**	**FY05**
	6.1 Total	9.6	10.1	9.3	9.2	11.0	12.2	13.3	13.2	12.5	11.9	11.3	10.1
	6.2 Total	19.2	24.5	33.8	37.5	32.5	28.7	33.0	28.3	26.2	25.3	28.8	29.7
	6.3 Total	14.0	18.6	17.9	15.2	16.5	20.3	18.5	14.5	15.6	17.1	14.2	15.7
	S&T Total	42.8	53.1	61.0	62.0	60.0	61.2	64.8	56.0	54.3	54.3	54.3	55.5

[1] Source: FY94 – FY00 actuals derived from analysis of R-2 Exhibits and PBR-01. FY01 – FY04 estimates derived from PBR-01.

Army Behavioral, Cognitive and Social Sciences Research Funding Summary

(Constant FY01 $ in Millions)[2]

PE/PROJ	PE/PROJ TITLE	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
0601102A	**Defense Research Sciences**												
74A	Human Engineering	2.9	2.6	2.3	2.4	2.6	2.3	2.6	2.7	2.7	2.7	2.7	2.6
74F	Personnel Performance & Training	3.4	3.0	2.8	2.5	2.5	2.1	2.7	2.8	2.8	2.8	2.8	2.8
	Total	6.3	5.6	5.1	4.8	5.1	4.4	5.4	5.5	5.5	5.5	5.4	5.4
0601104A[3]	University & Industry Research Ctrs												
H56	Advanced Displays Research			5.0	4.5	4.5	4.3	7.0	6.0	5.9	5.9	5.9	5.9
H59	University Centers of Excellence							2.0					
J08	Institute for Creative Technologies								8.2	4.3	4.3	4.3	4.4
	Total			5.0	4.5	4.5	4.3	8.9	14.2	10.2	10.3	10.3	10.3
0602308A[3]	Advanced Concepts & Simulations												
C90	Modeling & Simulation for Training & Design		14.1	8.2	9.6	9.8	8.5	10.4	10.6	10.6	10.5	11.6	12.1
D02	Distributed Interactive Simulations								8.0	2.9	3.8	4.7	5.5
	Total		14.1	8.2	9.6	9.8	8.5	10.4	18.5	13.6	14.4	16.3	17.6
0602716A	**Human Factors Engineering Technology**												
H70	Human Fact Eng Sys Dev	17.3	14.3	13.0	14.4	14.4	13.5	16.6	15.8	16.2	15.9	15.7	16.0
0602785A	**Manpower/Personnel/Training Technology**												
790	Personnel Performance & Training Technology	3.9	3.3	2.7	3.1	11.2	8.5	12.2	11.9	11.7	11.7	11.6	11.5
791	Education & Training Technology	9.7	7.4	5.0	6.6								
	Total	13.6	10.7	7.8	9.7	11.2	8.5	12.2	11.9	11.7	11.7	11.6	11.5
0603003A[3]	Aviation Advanced Technology												
B39	Advanced Distributed Simulations	2.7											
0603007A	**Manpower, Personnel & Training Advanced Technology Development**												
792	Personnel Performance and Training	4.8	2.9	2.3	1.4	4.1	3.0	5.1	3.1	3.1	3.0	3.5	3.6
793	Training Systems and Education	4.2	2.4	2.6	3.1								
	Total	9.0	5.3	4.9	4.5	4.1	3.0	5.1	3.1	3.1	3.0	3.5	3.6
Army Account Roll-up		**FY94**	**FY95**	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**FY01**	**FY02**	**FY03**	**FY04**	**FY05**
	6.1 Total	6.3	5.6	10.1	9.3	9.6	8.7	14.3	19.6	15.7	15.7	15.7	15.7
	6.2 Total	30.9	39.1	29.0	33.7	35.3	30.5	39.2	46.2	41.4	42.0	43.6	45.1
	6.3 Total	11.7	5.3	4.9	4.5	4.1	3.0	5.1	3.1	3.1	3.0	3.5	3.6
	S&T Total	48.8	50.0	44.0	47.5	49.1	42.2	58.6	68.9	60.2	60.7	62.8	64.5

[2] Source: FY94 – FY00 actuals derived from analysis of R-2 Exhibits and PBR-01. FY01 – FY05 estimates derived from PBR-01.
[3] This project line is currently categorized within Reliance in the Information Systems Technology Area.

Navy Behavioral, Cognitive and Social Sciences Research Funding Summary

(Constant FY01 $ in Millions)[4]

PE/PROJ	PE/PROJ TITLE	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
06011053N	**Defense Research Sciences**	13.2	13.1	11.6	10.7	9.9	11.0	10.9	11.4	11.1	11.1	11.1	11.2
0602233N	**Human Systems Technology**	17.1	20.0	18.9	18.5	13.4	13.8	11.3	14.0	14.4	12.9	12.6	12.1
0603707N	**Manpower, Personnel & Training Advanced Technology Development**	19.2	20.2	18.5	19.5	20.7	21.7	22.3	22.0	22.4	19.8	19.2	18.3

Navy Account Roll-up	**FY94**	**FY95**	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**FY01**	**FY02**	**FY03**	**FY04**	**FY05**
6.1 Total	13.2	13.1	11.6	10.7	9.9	11.0	10.9	11.4	11.1	11.1	11.1	11.2
6.2 Total	17.1	20.0	18.9	18.5	13.4	13.8	11.3	14.0	14.4	12.9	12.6	12.1
6.3 Total	19.2	20.2	18.5	19.5	20.7	21.7	22.3	22.0	22.4	19.8	19.2	18.3
S&T Total	49.5	53.3	49.0	48.7	44.0	46.4	44.5	47.4	47.9	43.9	42.9	41.6

[4] Source: Same as footnote 2, except Basic Research funding supplied by ONR Comptroller.

Appendix C -
Program Descriptions of Institutional Investments[1]

AIR FORCE

0601102F - DEFENSE RESEARCH SCIENCES

2313 - Human Performance

Human Performance research examines all aspects of human information processing critical to Air Force operations. The overall objective is to develop useful, quantitative models of the way people: perceive, navigate, and manipulate their environment; make decisions in complex tasks under stress or uncertainty; and adapt to extreme sensory, biophysical, or cognitive workloads. The sensory component emphasizes visual, auditory, vestibular, and kinesthetic systems and their optimal integration. Focused investigations seek the scientific foundation for several developing Air Force technologies including the design of interactive displays, virtual reality simulators, intelligent control systems, sensors and fused-image displays, and adaptive systems for personnel training and selection. The primary areas of research investigated by this project are sensory and perceptual systems, cognition, and cognitive workload.

0602202F - HUMAN EFFECTIVENESS APPLIED RESEARCH

1121 - Training Development and Assessment Technology

This project develops technology to accelerate learning, increase skill/knowledge retention, and enhance job performance. This effort also develops cost-effective methods for designing, delivering, and evaluating training. Increased Air Force use of advanced technology and changes in the overall qualifications of the recruit pool add challenge to the already demanding task of effectively training Air Force recruits. This project was reprogrammed into PE 0602202F/1123 in FY96.

1123 - Manpower, Personnel and Training Technology

This project develops and evaluates new methods and technologies in support of Air Force training and education requirements in a variety of specific areas, including: aircrew training; technical training; logistics training; mission rehearsal; training in support of complex decision making; space operations training; information warfare training; and warfare readiness training. It investigates the spectrum of new and advanced training and education technologies for optimal ways to determine needs and deficiencies, design and implement training, and evaluate training effectiveness. It develops and evaluates specific training systems, desktop tutors, courseware development tools and technologies, assessment methodologies, and simulation-based systems to determine how to achieve maximum learning effectiveness for specific needs at minimum cost. This project will contribute to a more highly trained and flexible cadre of personnel and reduce the cost of maintaining crew, aircraft, and support personnel readiness. This program develops technologies to increase operational readiness by providing more effective methods and approaches to classify, assign, train, assess, and retain personnel. This program focuses on reducing the manpower required to operate and support weapon systems and on improving the effectiveness of the operators, maintainers, and other support personnel for those systems.

[1] Descriptions taken from applicable RDDS (Research and Development Descriptive Summaries)

7184 - Human Effectiveness Applied Research/Crew Technology
This project develops the technology required to improve human performance, protection, and survivability in operational environments. This is accomplished by defining the physical and cognitive parameters, capabilities, and limits of systems operators; determining human responses to operational stresses such as noise, impact, vibration, sustained acceleration, spatial disorientation, altitude, workload, and sustained operations; and optimizing the human-machine interface. The project produces human-centered design criteria, guidelines, and automated design tools for the development of effective technologies for information display, team communications, crew scheduling and fatigue management, control interfaces, crew station layout and functional integration, emergency escape, crash protection, aircrew oxygen systems, acceleration protection, and aircrew life support.

7719 - Force Acquisition and Distribution Technology
This project develops personnel qualification and aptitude measurement methods, job specification standards, and manpower and personnel models to provide methods and tools for optimal selection, classification, and assignment of personnel. This project was reprogrammed into PE 0602202F/1123 in FY96.

0603227F – PERSONNEL, TRAINING AND SIMULATION TECHNOLOGY

2743 - Advanced Training/ Force Management
This program develops and demonstrates technologies that will result in improved warfighter readiness. Develops, demonstrates, and evaluates technologies for Distributed Mission Training (DMT) including realistic, effective, and affordable synthetic combat environments, technologies for long distance networking to enhance joint-service training, visual displays for real-time and post-mission debrief, and instructional strategies to support warfighter training in a joint synthetic battlespace. Provides a technology testbed for examining warfighter skills, cognitive functions, and behaviors contributing to combat readiness. Develops models to support aircrew, space, and information operations, performance measurement systems for air, space and information warfare, and tools for mission planning, rehearsal, execution, and force protection in a distributed mission environment. Develops and demonstrates technologies necessary to provide realistic training for nighttime warfighting. Develops and demonstrates computer-based intelligent tutoring technology for representative tasks in high technology jobs, and software to enable Air Force training developers to rapidly and affordably build intelligent computer assisted training systems which continually interact with students for effective individualized training. Develops and demonstrates information management technology for the warfighter at the unit level. Work concentrates on aircrew, space, and information dominance domains. Note: In FY 2000, Congress added $1.5 million for Behavioral Science Research under AFRL (Air Force Research Laboratory).

2922 – Manpower and Force Management
This project develops technologies to improve weapon system life cycle manpower estimates, joint job structures and classification, and aircrew selection. This project includes technologies to analyze Manpower, Personnel, and Training (MPT) factors early in weapon systems design and acquisition to ensure the factors are supportable and to enable trade offs to accommodate MPT limitations and costs. This project was reprogrammed into PE 0603227F/2743 in FY98.

2949 – Advanced Training Technology
This project develops and demonstrates computer-based intelligent tutoring technology for representative tasks in high-technology jobs and software enabling Air Force training developers to rapidly and affordably build intelligent computer-assisted training systems which

continually interact with students for effective individualized training. This project was reprogrammed into PE 0603227F/2743 in FY98.

0603231F – CREW SYSTEMS AND PERSONNEL PROTECTION TECHNOLOGY

2829 – Crew-Centered Cockpit Design

This project develops, demonstrates, and transitions technology for design and modification of crew stations that will enhance aircrew performance and safety. Using systems engineering, human factors principles, mission requirements, and crew capabilities, the project develops rigorous, traceable, and human-centered ways to design and test cockpits. This project was reprogrammed into PE 0603231F/2830 in FY98.

2830 – Crew Stations, Life Support and Escape

This project provides technology to improve operator combat performance; develop rigorous, traceable human-centered design tools; protect aircrews from physiological stresses such as high altitude, high G-forces, high temperature, and aerodynamic forces; and reduce aircrew fatalities and major injuries in emergency ejections at high-speed and at low-altitude, adverse-attitude flight conditions, while improving supportability, affordability, and accommodating the full range of the pilot population.

3257 – Helmet-Mounted Sensory Technologies

This project develops and demonstrates advanced helmet-mounted subsystem technologies to improve mission effectiveness and pilot situational awareness during day and night missions in all-weather conditions. Through the development of advanced helmet-mounted tracker and display (HMT/D) technologies, pilots will be able to detect, identify, target, and launch weapons faster and more accurately. This project develops technology for improved aircrew night vision goggles (NVG) to enhance aerial combat capabilities at night. It also develops technologies to protect against lasers and methods to evaluate the biological effects of laser weapons and high-energy laser systems.

ARMY

0601102A – DEFENSE RESEARCH SCIENCES

B74A – Human Engineering

This project supports research on soldier performance, including the areas of visual, auditory, cognitive, and stress-related performance. The objective is to identify, describe and manage underlying human-system interface factors critical to the design of Army weapon systems. The work in this program is consistent with the Army Science and Technology Master Plan (ASTMP), and the Army Strategic Research Objectives (SROs).

B74F – Personnel Performance and Training

This project conducts behavioral science research in areas with high payoff opportunities for improved training, leadership, and personnel performance, including: methods for faster learning and improved skill retention; leader effectiveness for improved team and unit performance; understanding the impact of societal trends on Army readiness; and improving the match between soldier skills and their jobs to optimize performance. Research is focused on issues of small-team performance, leadership, and training to ensure that personnel performance and training research keep pace with future mission, structural, technological, equipment, and personnel changes.

0601104A – UNIVERSITY AND INDUSTRY RESEARCH CENTERS

H56 – Advanced Displays Research

This project supports a competitively selected university/ industry consortium that was formed to provide solutions for the many requirements for information assimilation on the battlefield. The focus of the consortium is to develop more powerful and more user friendly computer displays and information control constructs to provide access to all information of practical use and provide data visualization in an efficient manner without overwhelming the user. Work in this project differs from the Defense Advanced Research Projects Agency's (DARPA's) program, which aims to establish a domestic capability for display hardware. The technical areas being addressed under this project are: human- computer interface in an information rich environment; display configuration, real time visualization, architecture, information presentation, and control coupling.

H59 – University Centers of Excellence

This task in FY00 involved the following: (a) Link entertainment industry and defense through the development of a center, the Institute for Creative Technologies, to research networked, realistic simulation tools focused on incorporating entertainment industry methods and data into combat training devices (moved to Project J08 in FY01); (b) Explore emerging entertainment technologies that may be applicable to meet future Army training needs (moved to Project J08 in FY01); and (c) Research applicability of entertainment database tools and methods for use in Army modeling and simulation (moved to Project J08 in FY01).

J08 – Institute for Creative Technologies

This project supports simulation and training technology research at the Institute for Creative Technologies (ICT) at the University of Southern California, Los Angeles, California. ICT was designated in August 1999 by DDR& E as a University Affiliated Research Center (UARC) to support Army training and readiness through research into simulation and training technology such as mission rehearsal, leadership development, and distance learning. ICT will actively engage industry (multimedia, location- based simulation, interactive gaming) to exploit dual-use technology. ICT will serve as a means for the military to learn about, and benefit from entertainment technologies, and enable their transfer into military systems. ICT will also work

with creative talent from industry in order to adapt their concepts of story and character to increasing the degree of immersion experienced by participants in synthetic experiences, and to improving the utility of the outcomes of these experiences. In return, industry will leverage the DoD sponsored research being done by the Modeling and Simulation UARC. Creating a true synthesis of creativity and technology and of the capabilities of industry and the R& D community will revolutionize military training and mission rehearsal by making it more effective in terms of cost, time, the types of experiences that can be trained or rehearsed, and the quality of the result. It will also allow the United States to maintain dominance in simulation and training technologies.

0602308A – ADVANCED CONCEPTS AND SIMULATIONS

C90 – Modeling and Simulation for Training and Design

This program provides and demonstrates enabling technologies for advancing distributed interactive simulation in the synthetic environment. AC90 provides the representation of the battlefield needed to support the use of modeling and simulation as an acquisition and training development tool. C90 provides a virtual representation of a lethal combined arms environment with the warfighter- in- the- loop that closed- form analysis cannot provide. The environment permits new system concepts, tactics and doctrine and test requirements to be evaluated with a warfighter- in- the- loop in a combined arms battlefield throughout the acquisition life cycle at a reduced cost and time compared to the traditional approach. The research being conducted includes embedded simulation, intelligent forces representation, rapid and cost- effective generation of synthetic environments, simulation interface and linkage technologies, and complex data modeling and interchange..

D02 – Distributed Interactive Simulations

This project is a restructure from Project C90 and enables the rapid transfer and development of simulation and training technology research results to the Army from the Institute for Creative Technologies (ICT) at the University of Southern California, Los Angeles, California. ICT was designated in August 1999 by DDR& E as a University Affiliated Research Center (UARC) to support Army training and readiness through research into simulation and training technology such as mission rehearsal, leadership development, and distance learning. ICT will actively engage industry (multimedia, location- based simulation, interactive gaming) to exploit dual-use technology. ICT will serve as a means for the military to learn about, and benefit from entertainment technologies, and enable their transfer into military systems. ICT will also work with creative talent from industry in order to adapt their concepts of story and character to increasing the degree of immersion experienced by participants in synthetic experiences, and to improving the utility of the outcomes of these experiences. In return, industry will leverage the DoD sponsored research being done by the Modeling and Simulation UARC. This project will ensure the transition of the research into the Army tech base and future Army training products. Creating a true synthesis of creativity and technology and of the capabilities of industry and the R& D community will revolutionize military training and mission rehearsal by making it more effective in terms of cost, time, the types of experiences that can be trained or rehearsed, and the quality of the result. It will also allow the United States to maintain dominance in simulation and training technologies. The US Army Simulation Training and Instrumentation Command (STRICOM) in Orlando, Florida, will develop new Army training systems from the transitioned technology. STRICOM is collaborating with the Battle Command Battle Laboratory (BCBL) at Ft. Leavenworth, Kansas, which is working on the Training, Leadership Development, and Soldier Support (TLS) issues for contingency forces and operations. Funding for this program was enhanced through PBD 203C in FY 2001 to support applied research on more effective and immersive synthetic environments..

0602716A – HUMAN FACTORS ENGINEERING TECHNOLOGY

AH70 – Human Factors Engineering Systems Development

This program focuses on maximizing the effectiveness of the soldier in concert with his materiel, in order to survive and prevail on the battlefield. Specialized laboratory studies and field evaluations are conducted to collect performance data on the capabilities and limitations of soldiers, with particular attention on soldier and equipment interaction. The resulting data are the basis for weapon systems and equipment design standards, guidelines, handbooks and soldier training and manpower requirements to improve equipment operation and maintenance. Application of advancements yields reduced workload, fewer errors, enhanced soldier protection, user acceptance, and allows the soldier to extract the maximum performance from the equipment.

0602785A – MANPOWER/PERSONNEL/TRAINING TECHNOLOGY

A790 – Personnel Performance and Training Technologies

The objectives of this program are to provide the scientific basis to improve the selection and classification procedures to ensure the right person is placed in the right job, to determine leader skills and requirements for the future, to evaluate the impact of deployments on personnel issues (e. g., career commitment, retention, etc.), and to provide the behavioral technologies required for the development of effective individual and collective (unit) training strategies. Research topics include training strategies for the digitized battlefield, training strategies in simulated environments, optimum designs and utilization of simulators and training devices to achieve maximum learning at minimum cost, and modernization of the selection and classification systems to maintain warfighting capabilities in a downsized Army. Research in this PE is consistent with the Army Science and Technology Master Plan, the Army Modernization Plan, and Project Reliance and supports the Human Systems – Personnel Performance and Training – Defense Technology Area. The U. S. Army Research Institute (ARI) for the Behavioral and Social Sciences manages this PE.

A791 – Education and Training Technology

The objectives of this project are to provide the behavioral technologies required for the development of effective individual and collective (unit) training strategies using simulation-based synthetic environments. Research conducted in this project builds on recent advances in the cognitive sciences and will provide an empirical basis for improved collective (unit) training strategies and techniques for brigade and below, with focus on the digitized battlefield of the future. It will develop training methods to improve night operations, individual training strategies exploiting "virtual reality" technology for training and rehearsal of warfighting missions and stability operations, and determination of requirements for cost-effective simulator training on selected aviation tasks. Research under this project directly supports the training systems Defense technology area. Beginning in FY1998, this research is restructured to project A790.

0603003A – AVIATION ADVANCED TECHNOLOGY

B39 – Advanced Distributed Simulations

The Battlefield Distributed Simulation-Developmental (BDS-D) program simulation capabilities will be used for demonstrating and assessing advancements in distributed large scale, networked real-time, man-in-the-loop, upward compatible simulation architectures, and emerging tri-service/industry standards and methods for representing battlefield behaviors through use of selective levels of simulation fidelity and network participation. In FY 95, the BDS-D program is supported by PE 0602308A, Project C90.

0603007A – MANPOWER, PERSONNEL AND TRAINING ADVANCED TECHNOLOGY

A792 – Personnel Performance and Training
The objective of this program is to develop and demonstrate soldier- oriented technologies to enhance soldier and unit performance. The reduction of training and other personnel costs through the development of effective training strategies that incorporate appropriate mixes of live, virtual, and constructive simulations is also a key goal of this program. Research and development (R& D) efforts include designing new ways to efficiently develop collective training; developing and demonstrating prototype training methods and programs that improve mission performance, devising training strategies using distributed training technology to conduct multi- site training, assessment, and feedback; and evaluating the effectiveness of compressed gunnery training strategies for the Reserve Component. R& D will also design innovative methods and technologies to develop effective leaders for small team operations and for developing Battle Commanders for the digitized battlefield. Work in this program element is consistent with the Army Science and Technology Master Plan, the Army Modernization Plan, and Project Reliance. This PE is managed by the U. S. Army Research Institute (ARI) for the Behavioral and Social Sciences.

A793 – Training Systems and Education
The objective of this project is to demonstrate empirically based cost-effective training strategies, with particular emphasis on how to best use distributed interactive simulation (DIS) training environments. This program is predicated on research showing that the effectiveness of training aids, devices, simulations, and simulators (TADSS) is largely a function of how they are used in training, including the adequacy of performance measurement techniques and performance feedback methods. Training strategies will be developed to integrate all three types of simulation (live, virtual and constructive) into a seamless training environment that will enhance training quality, relevancy and efficiency for warfighting missions and for stability operations. This research supports the TRADOC Battle Labs and will utilize emerging Battlefield Distributed Simulation-Developmental (BDS-D) capabilities. This program supports the Training Systems Defense Technology Area. Beginning in FY1998, this research is restructured to project A792.

NAVY

06011053 – DEFENSE RESEARCH SCIENCES

Cognitive and Neural Science

Human Performance

Research in human performance influences the approach to personnel selection, assignment, and training. It also explores ways to augment personnel performance in military environments and to develop new ways of organizing better, more effective teams and command and control organizations. In research on teams and organizations, the Navy concentrates on coordination in distributed groups and models for evaluating organizational design. In the areas of cognition, learning, and memory, the Navy emphasis is on artificial intelligence (AI) and AI-based models of cognitive architecture. Navy research also focuses on teleoperated undersea requirements, automatic target recognition for precision strike missions, and auditory pattern recognition for sonar signal analysis. More generic principles of human image communication and sound localization are being investigated by the Air Force.

Reverse Engineering

The reverse engineering subarea exploits the unique designs of biological neural systems by discovering novel information processing architectures and algorithms potentially implementable in engineered systems. These efforts seek to imbue machine systems with capabilities for sensing, pattern recognition, learning, locomotion, manual dexterity, and adaptive control that approximate human functionality. The current Navy program in reverse engineering combines neurosciences and computational modeling in five topical areas: vision, touch/manipulation, locomotion, acoustics/biosonar, and learning.

0602233N – HUMAN SYSTEMS TECHNOLOGY

Personnel, Training and Human Factors

Personnel, Training, and Human Factors technologies enhance the Navy's ability to select, assign, and manage its people; to train effectively and affordably in classroom settings, in simulated environments, and while deployed; and to operate effectively in the complex, high-stress, information-rich and ambiguous environments of modern warfare. Technology development in these areas responds to a variety of requirements, including: providing more affordable approaches to training and skill maintenance; managing the force efficiently and maintaining readiness with fewer people and smaller budgets; providing warfighting capabilities optimized for low-intensity conflict and littoral warfare; and operating and maintaining increasingly sophisticated weapons systems.

0603707N – MANPOWER, PERSONNEL AND TRAINING ADVANCED TECHNOLOGY DEVELOPMENT

Human Factors Engineering

This project develops information management techniques, advanced interface technologies, and Decision Support Systems, all of which help ensure that complex systems will be operated and maintained more effectively, with fewer human-induced errors, and with greater safety.

Manpower and Personnel

This project provides Navy personnel system managers with the ability to attract and retain the right people and to place them in jobs that best use their skills, training, and experience. Fleet readiness can be enhanced and personnel costs reduced via such technologies as modeling and simulation, mathematical optimization, advanced testing, statistical forecasting, information visualization, data warehousing, data cleansing, web-based knowledge management, and human performance measurement.

Training Systems

This project improves mission effectiveness and safety by applying both simulation and instructional technology to the design of affordable education and training methods and systems. The project develops and evaluates systems to improve basic through advanced individual and team training, skill maintenance, and mission rehearsal capability. It improves training efficiency and cost-effectiveness by applying operations research, modeling and simulation, and instructional, cognitive, and computer sciences to the logistics, development, delivery, evaluation, and execution of training.

Appendix D -
APA Citation to MPT Labs of the Services

AMERICAN PSYCHOLOGICAL ASSOCIATION

June 14, 1996

PRESIDENTIAL CITATION

Presented to

THE MANPOWER, PERSONNEL AND TRAINING
RESEARCH LABORATORIES OF THE ARMY, NAVY AND AIR FORCE

On the occasion of the June 1996 meeting of its Board of Directors, the American Psychological Association formally recognizes the Armed Services for their enormous contributions to the behavioral and social sciences. Research conducted and sponsored by the Army Research Institute, the Navy Personnel Research and Development Center and the Air Force Human Resources Laboratory has been instrumental in the development and application of many of psychology's most important concepts and techniques.

In the field of testing, psychometrics, and statistical methodology, the Services have led the development of large-scale cognitive abilities testing, performance measurement, and computer-based testing. Through this research and development, the behavioral sciences have gained advances in item response theory and stanine test metrics, as well as general linear modeling techniques with binary predictors. We owe to the Services the establishment of the Gordon-Cleary model of test bias, a standard method used to examine group differences in testing.

In training and education, the Services led the field in Instructional Systems Design methodology, as well as computer-based training techniques, to include interactive video training systems. This research has made significant contributions to several theoretical and applied models of human cognition, decision making, skill acquisition, and long-term knowledge retention.

In personality and social psychology, research by the Service laboratories was instrumental in the evolution of today's widely accepted five factor theory of personality and its applications in personnel selection and placement. Modern concepts of leadership also owe their existence to work conducted and supported by these laboratories. Survey research into attitudes about race and culture, and the subsequent development of training to improve coworker relations, has contributed significantly to the social psychological literature, as well as to many civilian applications. Industrial/organizational psychology has benefitted from the Services' research in job analysis techniques that refined task analysis and cognitive task analysis approaches. The Service laboratories have been leaders in developing methods and applications of performance measures, such as the widely used critical incident technique.

The contributions of these three laboratories to psychology and to society is probably unmatched by another public or private agency. I take distinct pleasure in presenting the Armed Services with this Presidential Citation on behalf of the American Psychological Association.

Dorothy W. Cantor, PsyD, President