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EXECUTIVE SUMMARY

The nurturing of the national industrial technology base presents DoD with many challenges in today's defense environment. Reduced budgets in the coming years can weaken the supporting industrial base unless DoD can find ways to leverage the broader commercial technology base. Although DoD has come to increasingly rely on commercial capabilities at the component and assembly level, it has traditionally had trouble fully exploiting commercial technologies and products. This failure, along with the lack of a DoD manufacturing strategy which capitalizes on improvements in manufacturing techniques, and a needed emphasis on product quality and costs, represent missed opportunities to offset the impact of spending cuts.

Also of great concern is the increased influence and interest of foreign firms and governments in critical US industries and dual-use technologies. Foreign governments have been much more effective at focusing their attention (and resources) to global technology competitiveness in dual-use areas of significant national security importance. The DoD may in the future become reliant on foreign sources of technology in order to field "leading edge" military systems. Further, foreign acquisition can potentially threaten assured DoD access to needed products and technology.

To date, the Defense Department has formulated "Defense Critical Technologies Lists" which identify areas of concern but has not yet developed a comprehensive "Defense Technology Investment Strategy" which addresses all of these concerns. This Task Force was tasked to aid DoD in the formulation of such an investment strategy including the examination of the full range of technologies both here and abroad and the identification of those with high potential to provide "leap frog" capabilities to US forces for the next twenty years. Technological, industrial, and defense trade dimensions were evaluated.

This Task Force examined two broad areas related to technology and technology transfer policy: issues concerned with a technology investment strategy, and with the defense industrial base.

Technology Investment Strategy

With respect to investment strategy, our focus was on three aspects: (1) the process needed to develop and execute a successful strategy; (2) a methodology for identifying critical technologies, defined here as technologies offering an "order-of-magnitude" improvement in military capability; and (3) means of avoiding technological surprise, to which we have added the detection of technological paradigm shifts.

In review of DoD efforts we found that a good foundation exists for building a coherent technology investment strategy and an integrated management process:

- The US has world class capability in most technologies (and most weapons systems).
- There is currently a large cadre of dedicated scientists and engineers.
- Excellent examples exist of management processes which work.

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- The US has an excellent industrial base in most technical areas of importance to national security.

BUT...

- Unified, DoD-wide "strategies" and guidance are just now being initiated.
- There are missing links between scenarios, military capabilities, technology goals, and investments.
- There is a lack of accountability, measurement, and reward at all levels.
- There is poor visibility of both the input and output of DoD's Science and Technology (S&T) programs.
- There is underinvestment in process and manufacturing technologies.
- "Critical Defense Industry" and "Leveraging Commercial Base" are not being addressed.
- The importance and unique characteristics of the S&T program are not reflected in OSD management of the S&T program.

The Task Force concluded that the S&T program is so important that the USD(A) himself must play a leading role in DoD efforts to improve Technology Base strategy, resource management, and evaluation. Approximately \$6 billion, plus the applicable portions of SDI is currently being spent on technology development (6.1, 6.2, 6.3A). This is relatively small compared to the total defense budget. Although this size might indicate the need for a proportionately small demand for management attention, this is not, and cannot be, true. The tremendous leverage offered by the technology base --- leverage in future force capability, reduced systems costs, availability and reliability of fielded systems --- demands increased attention and leadership from the highest levels of OSD.

RECOMMENDATION: USD(A) establish a permanent executive position, the equivalent of a "corporate CEO" position, reporting directly to USD(A) and solely responsible for the formulation and execution of the DoD Science and Technology program. It should be noted that this position differs from the position of DDR&E in that it has both TOA authority and execution responsibility. It is envisioned that the DDR&E would continue to coordinate activities other than the S&T base.

Implementation of this recommendation would:

- Place exclusive responsibility and authority for the DoD S&T program firmly in the hands of one person. We believe this to be absolutely vital. Apart from any other management reforms related to the total DoD RDT&E program which may be desirable, which we did not address, we believe that there must be one person with exclusive responsibility for S&T. There is currently no such person; while the current position of DDR&E nominally has responsibility for all S&T except that of SDIO, the position has responsibility for many other non-S&T matters as well, and does not have S&T TOA authority. We do not believe that any position which has significant non-S&T responsibilities will provide for adequate OSD management of the DoD S&T program. Although we did not conduct a detailed management organization review to determine the proper organizational location of such a position, it obviously must be consistent with the responsibility and authority assigned.

- Provide centralization of the following functions as the responsibilities of the "CEO":
 - Development of policy for all S&T matters
 - Development and oversight of the execution of a single, unified DoD technology investment strategy, including goals, objectives, priorities, and resource allocations
 - Establishment of the S&T TOA for each DoD Component
 - Approval/disapproval of the S&T plans and programs of the DoD Components
- Provide decentralization of the following functions as the responsibilities of the DoD Components:
 - Development of detailed S&T plans and programs of the DoD Components
 - Execution of S&T programs of the DoD Components
 - Control of S&T personnel and facilities of the DoD Components

We would also expect the "CEO" to champion specific initiatives, such as:

- Selective technology demonstrations to lower risk, evaluate military worth and preserve critical design teams. 6.3A platform emphasis should be reduced accordingly
- Selective joint Service projects where contributions can be synergistic
- Implementation of evolutionary system improvements by relevant technology insertion
- Innovative high risk/high payoff technology development as an important segment of the total program
- Development of process and manufacturing technologies, both hard (process equipment) and soft (factory C³)
- An IR&D level that is no less than the current level, with proposed increases to accommodate manufacturing technology development
- Placement and continued development of quality personnel at all levels

To Support this recommendation, the Task Force also recommended that:

- Heads of DoD Components establish Service and Agency program executive officers (PEO's) responsible jointly to the CEO and the Service Acquisition Executive for technology investment strategy execution.

- Chairman, JCS establish a JCS organization focused on integrating tactics, doctrine, and technology. Along with this, develop necessary policies and procedures to support a scenario-based technology planning approach.
- DepSecDef increase the current level of technology base (6.1, 6.2, 6.3A) funding for future technological leadership, but tied to major reforms.

If this recommendation is implemented, the Task Force believes that many of the weaknesses identified above can be overcome.

Defense Industrial Base

In the area of the defense industrial base, our focus was also on three aspects: (1) the harmonization of the defense industrial base with the commercial industrial base; (2) assuring access to foreign components and/or technology, as necessary for military capability; and (3) technology transfer policy to various nations. Our findings are summarized below:

Leveraging Commercial Industrial Base. The current DoD "culture" is to maintain a separate defense industrial base; however, the decreasing defense budgets require selective reliance on the commercial industrial base (technology, cycle time, cost, and responsiveness). On the other hand, DoD must continue its role as a major catalyst for the commercial technology base and the university S&T community in "dual-use" areas. Numerous studies (Packard Commission, DSB, DMB, etc.) have provided specific, complementary recommendations on how better to leverage the commercial industrial base but, **VERY LITTLE PROGRESS HAS BEEN MADE IN IMPLEMENTATION OF THESE RECOMMENDATIONS.**

Assured Access to Critical Components and Technology. The central issue of concern is the potential demise of capabilities in defense "critical industries"/"critical industry segments." To date, "critical industries" remain undefined and unidentified by DoD. Further, there is no DoD/US action plan for assuring access to critical components and technology. Some critical industry segments have already moved off-shore -- jeopardizing assured access.

Technology Transfer Policy. The Task Force found that the current control system is now outdated. Missile, nuclear and chemical capabilities are proliferating worldwide. Even today, Soviet technology acquisition methods are unchanged. Export controls over technologies that encourage a market economy and democratization in the Soviet Union are not receiving the special attention they deserve. Third country restrictions remain a problem for US industry. Foreign investment in US increasing sharply while assured US access is not currently considered in international transactions of technology.

RECOMMENDATION: USD(A) should fully implement recommendations of the 1986 and 1989 DSB Summer Study on the use of commercial components and practices and DMB concept of "integrated" commercial/DoD industrial base. Remove the barriers and measure implementation effectiveness. The Task Force had no new recommendations for

harmonizing the defense and commercial industrial bases. Rather, we reaffirm the recommendations made by previous DSB and DMB studies on the use of commercial components and practices, and the concept of an integrated commercial/defense industrial base.

RECOMMENDATION: USD(A) should implement the recommendations of the 1990 DMB/DSB Task Force on defense critical industries. The principle recommendations are to:

- Identify critical industries using the 7-point DMB/DSB criteria
- Establish organizational responsibility
- Develop tools to permit iterative policy analysis
- Develop (with industry) sector-specific actions
- Make more "creative" use of the Title III of the DPA
- Nurture harmonization of the defense/ commercial industrial base

RECOMMENDATION: The Task Force strongly urges DoD to reduce, but not eliminate, all export control lists. Emphasis should be reduced on end products (such as computers and semiconductors). End products are indirect contributors to military strength or the proliferation of ballistic missiles and nuclear weapons. Emphasis should be placed on certain enabling technologies, manufacturing equipment and complete integrated systems that have direct military and/or proliferation application.

RECOMMENDATION: SECDEF consolidate and streamline the DoD organizations for implementing all aspects of international defense trade, collaboration on acquisition programs, and technology transfer policy. We further recommend that the consolidation include, first and foremost, the assignment of sole responsibility for these implementation activities to an Assistant Secretary or Deputy Under Secretary level position reporting to USD(A). These activities include matters concerning defense industrial cooperation, government-to-government agreements, evaluation of foreign investment and critical industries, foreign military sales, and technology export control. This is the fourth time in three separate administrations that the DSB has made such a recommendation.

SUMMARY

The funding trends for Science and Technology have not been favorable. There has been a significant reduction in buying power over the past 30 years. In particular, the funding for the technology base (6.1, 6.2) has not kept pace with total RDT&E funding, declining from a peak of almost 25% of RDT&E funding in 1965 to less than 10% today. Nor has the advanced technology development (6.3A) funding devoted to components and subsystems increased significantly in the last ten years.

In the changing environment, DoD must:

- **Increase Science and Technology investment coupled to the implementation of a true technology investment strategy.**
- **Explicitly address the viability of its industrial base and draw far more heavily on the commercial sector.**

1. INTRODUCTION

1.1. BACKGROUND

The strength of the United States in science and technology (S&T) and our ability to incorporate advanced technology into both military and commercial products has been the mainstay of our military and economic strength. A key feature of our defense strategy has been to seek, through the application of superior technology, qualitative superiority in warfighting capabilities to counter the numerical superiority of our potential adversaries. The remarkable changes underway in the Soviet Union and Eastern Europe, and the related prospect of declining defense budgets, have altered in fundamental ways the future military capabilities which the United States will need. The reports of the other Task Forces of this Summer Study deal with the implications of these changes in terms of future scenarios and the qualitative nature of the military forces which will be necessary. One overriding implication is that we will need a much greater degree of flexibility than in the past, and a strong S&T base will become increasingly important if we are to achieve this flexibility.

This first concern, but not the only one, in a defense S&T base is the DoD S&T program. The primary goal of this program is to provide options for future military capability: that is, to develop or otherwise acquire technology that can be used with confidence by DoD to provide a wide range of military capabilities in the future. The S&T program is the initial phase of the more general DoD acquisition program and, in particular, provides the technological basis for system acquisition programs. In addition, the program serves to provide DoD with smart buyers; to support defense planning and operational problem solving; to preclude technological surprise; and to contribute to US global competitiveness through the development of dual-use technology.

The DoD S&T program is a broadly based program which addresses virtually all science and technology of direct interest to national defense. In Fiscal Year 1990, S&T funding is \$5.6 billion, plus the relevant portions of the \$3.6 billion Strategic Defense Initiative. It is categorized as 6.1, Research; 6.2, Exploratory Development; and 6.3A, Advanced Technology Development. It is important to make the distinction between the S&T program and the total DoD Research, Development, Test and Evaluation (RDT&E) program, which was \$36.7 billion in Fiscal Year 1990. The goal of the total RDT&E program is to develop new and/or improved operational military

systems. The S&T portion, in comparison to the remainder, is characterized by significant risk and uncertainty, and a time from gestation to fruition that can be very long.

Science and technology efforts directly related to national defense are not confined solely to the S&T program; they are considerably augmented by Industry Independent Research and Development (IRAD), which in Fiscal Year 1988 amounted to \$4.8 billion (approximately 50% of which was reimbursed by the government). IRAD is analogous to RDT&E, in that the bulk of the effort is devoted to near term development or improvement of products, but nevertheless an appreciable fraction is devoted to S&T efforts. On a national scale, S&T efforts are conducted by other government agencies and private industry (roughly \$15 billion per year) and these relate to defense through dual-use technology. Dual-use technology with both military and civilian applications, and sometimes originating in the commercial sector, plays an essential role in defense systems.

The DoD S&T community capitalizes on S&T efforts of allies through joint programs. However, it has been DoD policy not to depend solely on allies' efforts due to national security considerations. While the efforts of our allies are generally in the same areas as US efforts, their investments may be driven by concerns for global competitiveness as well as military superiority.

The changing defense and economic environment presents DoD with many difficulties in not only the planning and execution on its S&T program, but in nurturing the national industrial technology base as well. Reduced defense budgets in the coming years will certainly lead to a smaller defense-unique industrial base. Simultaneously, there is convergence between many commercial and military technologies with some commercial developments outpacing the military (e.g., electronics). Both of these factors suggest that a greater reliance by DoD on the commercial sector is necessary, but DoD has traditionally had trouble exploiting commercial technologies and products. In the same vein, improvements in manufacturing techniques now permit multi-product and low-volume efficiency. But DoD to date has not developed a manufacturing strategy, which would undoubtedly involve a closer integration with the commercial base. The increased level of foreign investment in the US has resulted in defense-related plants and technology being acquired by foreign firms, thereby resulting in potential threats to DoD's assured access to these products and technologies. Finally, foreign governments and multinational firms actively focus on dual-use technology for global competitiveness

reasons, which threatens the domestic industrial base which is necessary for national security purposes.

Dealing with these difficulties in an organized and effective way obviously requires a total technology strategy.

1.2. TERMS OF REFERENCE

This Task Force was tasked to aid DoD in the formulation of such an investment strategy including the examination of the full range of technologies both here and abroad and the identification of those with high potential to provide "leap frog" capabilities to US forces for the next twenty years. Technological, industrial, and defense trade dimensions were to be evaluated. Specifically, the Task Force was tasked to answer the following questions:

1. How should the DoD identify, assess the payoff of and prioritize critical technologies?
2. What are the technologies (product and process) that promise "order of magnitude" impact on the functionality, cost, schedule and/or quality of future military capability?
3. What specific technology base investment strategy should the DoD adopt in the future to insure quantum jumps in the capabilities of US forces across the range of possible future scenarios?
4. How can the DoD assure US access to world class technology and industrial production capabilities in areas critical to US national security?
5. In view of the changing economic and military environments, how should the US revise its technology transfer policies?

The terms of reference for this Summer Study are found in Appendix A and the participants are listed in Appendix B.

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1.3. AREAS OF FOCUS

The Task Force focussed on the following areas:

- **Investment Strategy**

- **DoD technology investment strategy process.** The fundamental foundation necessary to achieve and sustain an organization's objective is an effective investment strategy. As DoD faces an evolving new world, a comprehensive strategy to guide and control technology investments becomes the next order-of-magnitude improvement necessary. The process to develop a single, unified DoD Technology Investment Strategy has recently been initiated. The Task Force examined this process.
- **Identification and prioritization of critical technologies.** The Task Force was asked to formulate selection criteria and a methodology for identifying those technologies which are critical to national security. Included concerns were potential technological surprises and paradigm shifts that the panel could anticipate over the 20-year assessment horizon of the DSB Study. These help test the robustness of the selected critical technology aggregates.
- **Technological surprise and paradigm shifts.** The development of a DoD investment strategy for long-term development of critical technologies must ensure that proper attention is focused on anticipating, and defending against, sudden enhancements to an enemy's capabilities. Such "surprises" can evolve from two different mechanisms: Technology Surprises arising from the previously unforeseen (or discounted because of weak signals) use of an entirely new technological weapon or threat; or arising not so much from new technology, per se, but from the use of known technologies in new ways or within different doctrine and tactics. It is also useful to identify technological paradigm shifts as indicators of areas that might foster future surprise. The Task Force identified a set of areas which have the potential to provide "surprise."

- **Defense Industrial Base**

- **Harmonization with the commercial industrial base.** The US no longer dominates technology superiority nor cost competitiveness. A shift of technology advancement has taken place from the predominantly DoD-funded and controlled programs, to non-DoD commercial technology, over which DoD has less influence. This dual-use technology, from the commercial sector, is not only growing beyond the DoD pace of technology, but it can no longer be obtained solely from the US industrial base. As DoD faces these new challenges, harmonization with the commercial sector is mandatory. The Task Force evaluated this area.
- **Assured access to critical materials, processes, components and technologies for defense needs.** The Task Force was concerned about the potential demise of capabilities in defense "critical industries"/"industry segments" and recommends several DoD actions.
- **Technology transfer policy.** The last area of concern addressed by the Task Force was technology transfer policy. This area is quite important and changes are needed given the new technological and political environment of the 1990's.

The following caveats apply to the Task Force deliberations:

- There was no attempt to review individual science and technology programs in detail
- The Task force relied heavily on inputs from OSD, Service and Agency experts
- The Task Force did not address:
 - Those aspects of trade and industry competitiveness not directly related to DoD needs
 - DoD's overall management of science and technology programs, resources and in-house facilities.

2.0 INVESTMENT STRATEGY

2.1 TECHNOLOGY INVESTMENT STRATEGY

2.1.1 WHAT IS A TECHNOLOGY INVESTMENT STRATEGY AND WHY DOES DOD NEED IT?

A technology investment strategy is a fundamental foundation for achieving and sustaining DoD's objectives. Such a strategy is not only critical to ensure continuing introduction of new technology advances supporting improved military capabilities, but it is also mandatory to ensure the defense dollar is spent effectively for the right technologies at the right time. Additionally, an investment strategy is needed to focus attention and resources on the health and vitality of that portion of the industrial base which is fundamental to US national security.

For DoD, an effective technology investment strategy should identify and implement an integrated set of technical programs and policies that assures competitive (military) advantage within affordable economics. To accomplish this goal, we see four major components:

- A. Tying military needs to necessary technical capabilities and identifying milestones**
- B. Tying necessary technical capabilities to resource allocation**
- C. Balancing five areas of investment:**
 - 1. Critical technologies offering order-of-magnitude potential impacts**
 - 2. "Core technology" advancements**
 - 3. Countering "technology surprises" and paradigm shifts**
 - 4. Process and manufacturing technologies**
 - 5. Nurture government/industry infrastructure**
- D. Providing visibility and accountability**

The strategy should create strong conviction about its adequacy, provide multiple ways to achieve advantage (redundancy), and clarify risk. Needs must be translated, disaggregated and interpreted into technology objectives or capabilities that technologists can work upon. Resources, usually inadequate, need to be allocated to those technologies (or military needs) which have highest priority; a strategy must

balance resources among deserving technologies unequally but appropriately. A strategy which causes no change in direction or execution is highly suspect.

A good strategy is essential for ensuring that DoD:

- Develop technology options having great impact, by devoting appropriate effort to those critical technologies with exceptional impact and core technologies with pervasive impact
- Avoid technological surprise and be ahead of technological paradigm shifts
- Provide necessary manufacturing and process technology to effect systems which are both technologically advanced and affordable
- Promote leveraging of commercial and multi-national technology
- Improve the infrastructure

2.1.2 WHAT ARE THE MAJOR ELEMENTS OF A TECHNOLOGY INVESTMENT STRATEGY

A major focus of a technology investment strategy must be to ensure that technology options needed by DoD are available at the appropriate time. To achieve this end, the DoD technology investment strategy should include a number of elements. Warfare scenarios must be defined and relevant military needs/capabilities translated into technical objectives for technical programs/projects. Such a translation requires good understanding of military needs, their dependence on technology (both present and prospective) and feasible technical achievements within the relevant forecast/need timeframe.

Technologies must be targeted where US world-wide leadership is crucial to US national security interests. It is important to establish those technologies in which leadership is crucial for military success. In today's world, leadership across all technologies is probably not achievable.

A balance must be struck among technology objectives, milestones and resources. Objectives and milestones will vary considerably in precision, risk, and immediate application among the technologies of 6.1, 6.2 and 6.3A. However, they should exist for all projects. Milestones are particularly important since they clarify what will be

achieved and when. More specifically, they describe deliverables in readily understood and measurable terms; set dates for delivery; clarify risks of failure; and identify resources needed.

Technical interdependencies must be identified among projects ("aggregates") permitting technical progress superior to an adversary. For example, capability in integrated circuit design, manufacturing process development, IC packaging, and system integration, in total, provide capability beyond the sum of each individual skill. Such interdependencies or "aggregates" create ability to develop as of yet undefined weapons systems.

Clarity is needed on technologies not pursued, and the risk of not pursuing them. Since most investment strategies are resource constrained, an explicit assessment of unfunded technologies, and the risk associated with loss of leadership, is important.

Finally, some assurance is needed that the investments made, if successful, will provide a competitive capability. Such assurance is rarely unequivocal, but a high degree of probability might be expected. Anything less argues for revising the strategy, the individual investments, or "reach" of the projects. An investment strategy is adequate if it provides parity or slightly better than parity across technologies compared to competitors. A strategy is outstanding if it provides clear superiority in many technologies within available resources.

2.1.3 WHAT MANAGEMENT PROCESSES ARE NEEDED TO SUPPORT A TECHNOLOGY INVESTMENT STRATEGY

The necessary management process to create and maintain an investment strategy must also include a number of elements.

1. Clear goals, measurable results and accountability. Setting objectives and missions for technology is a critical step in the overall process. Success depends upon an inclusive process that permits a specific and precise definition of needs, coupled with a broad portfolio of available technology, or technology that might be developed. In a complex institution with a wide variety of competing needs, and an equally wide choice of technologies in which to invest, the process must permit many participants to contribute detailed knowledge, but also be able to relate their limited perspective and specialty to the whole. Frequently this is not done because it is

administratively difficult. A limited number of people are good at matching technology with missions. Involving those people more than others has high leverage. The test of whether goals are clear is a "bottom-first" process. Technical project leaders know whether goals established for their projects are clear. Conversely, measurable results are more likely to be understood at higher organizational levels by those who see many projects, understand needs and opportunities more clearly and may be able to assess necessary rate of progress. Combining different organizational levels in defining projects is desirable.

2. Clear and consistent resource allocation. Setting an overall funding level is usually a compromise between an analytically derived, bottom-up analysis of needs and a top-down judgement of affordability. The bottom-up requirements usually exceed available resources. This must be resolved early (often arbitrarily), in order to provide stability to the program. It is very important to segment funding so that it is as stable as possible, and fluctuations are concentrated in as few projects as possible.

3. Well-defined role and responsibility, particularly at organizational interfaces. If goals are clear and results measurable, then accountability may be assigned. Eventually, at some high level, accountability is finally clear. The art is to assign accountability close to the project, so that the dozens of minor initiatives and decisions required for success are taken with confidence. Even with accountability, clear goals and measurable results, project leaders act more slowly than necessary when they lack, or believe they lack, certain authorities. Here again, a "bottom-first" identification of what authority is needed, frequently modest, can be provided in enough degree to accelerate projects.

4. Good visibility of the entire program by participants. The strategy process must lead to a program structure which provides visibility between resource allocation and critical and core technologies. Participants at all levels must see efforts relevant to the projects they are pursuing. Further, the program output should have such visibility.

5. A well understood, efficient process. Another attribute of a successful program is a process that permits all parts of the organization to understand the planning process, the technical strategy and decision making. A simple process for decision-making gathers people to debate a technical program; rather than attempt to commit it all to paper and manage serially from a long distance. A simple process reduces the number of interfaces by segmenting the process so that "turf" boundaries do not isolate

or destroy cooperation among those with a common technical interest. A simple process is far more difficult to establish than a complex process.

6. Accommodates technology-push innovation and risk taking. The inherent nature of S&T efforts gives them significant degrees of risk and uncertainty. This attribute must be accepted by DoD leadership and project managers encouraged to push on the frontiers of new technology even in the face of possible failure. Technology-push projects which create military capabilities not yet needed or even seen as needed by operating forces should be pursued. This vital segment of the technology investment strategy requires a smaller amount of funding (10-20%) but has the potential to create significant "breakthroughs."

7. Consistent and coherent reward system. A set of objectives, well defined funding and well defined accountability are necessary, but not sufficient, for a successful technology investment process. In addition, a motivation or reward system must exist and must be consistent with the goals and objectives, the accountability and authority. "Consistent with" implies:

- **at the project manager level**, stable objectives with adequate resources, directed toward a real need. Further, success in one project must contribute to reasonable subsequent job assignments. Technical failure, if properly pursued, must be adequately valued.
- **at the Lab Director level**, reasonable participation in the direction of the lab, discretion over project direction, access to decision makers who affect the lab's funding, and reasonably stable objectives year to year. In this regard, the objectives of the Laboratory Demonstration project that is slowly moving through DoD could be helpful.
- **at the Service level**, organizational stability, or significant participation in change; plus a stability of program funding and objectives for the more important objectives/programs. Mutual respect for others in the authority chain who affect the Service.
- **at the USD(A) level.** No greater clarity of motivation, with respect to technology, is needed than at the USD(A) level, yet there is no position that has less stable, unclear, and conflicting motivation. This is critical, because stability for S&T cannot be gained without USD(A) active participation. Unlikely though it may be, a few Congressman, OMB, plus the Secretary, need to establish or concur with the USD(A) plans for stability with respect to

technology. Absent this, the entire technical program, including DDR&E, will be insufficiently stable, noticeably less effective and inefficient.

In order to create and maintain a good technical investment strategy, a management process should meet the criteria listed. The need for an orderly process is greater when:

- the organization has complex missions
- many technologies are pursued
- the consequences of missed opportunities are severe
- lead time and response/recovery time are long

Not meeting the criteria results in confusion at lower organizational levels in the short run; and missed opportunities or problems in the substantive program in the long run. Confusion at lower levels leads to slower accomplishment of technical objectives, uncertainty concerning the many smaller decisions within projects, and unnecessary turf disagreements, misunderstandings, and delays. Inconsistent or contradictory rewards can severely compromise the technical program through dysfunctional behavior such as not sharing technical information with internal "competitors", storing or hiding funds not needed, pursuing projects with little expectation of impact, and perceived capricious and arbitrary decisions and actions. Since a good management process is time-consuming to develop, priorities need to be set among the criteria for the short term.

2.1.4 FINDINGS

2.1.4.1 STRENGTHS

The starting point for considering improvements to the DoD technology investment strategy process is to evaluate the strengths (both implicit and explicit) of the current system. We find that there is in fact a good foundation upon which to base improvements.

US Has World Class Capability In Most Technologies (and Most Weapons Systems). The Department of Defense (DoD) Science and Technology (S&T) Program (6.1, 6.2, and 6.3A), through past investment, has developed state-of-the-art capability in most of the spectrum of technologies required to develop weapons

systems for force advantage. Indeed, this investment in S&T, implemented through the Service laboratories/centers and defense agencies, has been key in the elevation of the US to a position of world leadership in most current and emerging technologies, (e.g., microelectronics, computers, advanced materials, advanced aircraft). In the most recent (March 1990) DoD Critical Technologies Plan (DCTP), the broad leadership of the US in technology was clearly apparent, although other countries, particularly Japan, were significantly ahead in some niches of technology. This trend, of course, points up the concern of Congress (and the reason that the DCTP is mandated by public law to be prepared annually) that our technological edge is eroding, and this erosion will result in severe consequences for both the military and economic strength of the United States. Currently however, the national industrial base, built over the last several decades, is in good shape. Historically, it has provided the technologies and superior weapons systems which have formed the basis for major classes of US production and exports.

There is a Large Cadre of Dedicated Scientists and Engineers. Furthermore, the labs and centers of the DoD have a well-developed infrastructure which includes unique world class research and test facilities which would be extremely difficult to replace. Backing this capability is the large cadre of over 25,000 dedicated scientists and engineers who have been trained in areas of concern to the DoD. The capacity of US universities to produce this group of outstanding US citizen scientists and engineers, who provide this powerful and creative work force, has remained unmatched since the early days of this century. However, this talent pool will come under increasing strain as industry and academic compensation progressively outstrip Federal pay and psychic income.

Excellent Examples Exist of Processes Which Work. Although difficult without a clear, unified, and comprehensive OSD investment strategy, there are excellent examples of DoD technology planning. Among these are turbine engine technology (the Integrated High Performance Turbine Engine Technology (IHPTET) and microwave and millimeter monolithic integrated circuit technology developed in OSD-coordinated efforts which included the Services, DARPA, NASA and industry. We would expect many similar programs to be developed under a unified investment strategy process leading to a more effective S&T program. Unfortunately, these examples of cross-Service/agency cooperation are limited in number, and most of the working investment strategy processes which exist reside independently within the

Services and agencies. These Service investment strategy processes are constantly improving.

Widespread Activity is Ongoing to Improve the Defense Technology Investment Process. The Task Force found that a good foundation exists for building a coherent technology investment strategy and an integrated management process. Recently, an effort was initiated in the Office of the Secretary of Defense (OSD) to develop a DoD investment strategy which would ultimately integrate Service and defense agency plans. One investment plan, prepared with Service and Defense Agency participation, was published in June 1990 and appears to be a good first step in the development of a comprehensive, unified technology investment strategy. Subsequent editions were projected to include the incorporation of the DCTP, determination of funding priorities, and discussion of additional broad issues important to technology development such as personnel, facilities, and dual-use capabilities. Also, the second annual DCTP was published in March 1990 and, although not linked to warfighting capabilities, provided a beginning for the identification process. A second, separate DoD investment strategy appeared in July 1990 which was prepared independently by OSD. These documents, both in the Services and OSD, should serve as building blocks for the development of a unified, comprehensive DoD investment strategy for S&T. These ongoing DoD efforts are further described in Appendix C.

The industrial base of the US is excellent in most technical and related manufacturing areas. In spite of recent trends, the US industrial base remains very strong and retains world leadership in most technology areas of importance to DoD.

2.1.4.2 FINDINGS: WEAKNESSES

Although historically the foundation has had strength, all leadership elements are today vulnerable. The US technology and industrial base is being threatened globally; the DoD S&T talent pool will require new motivations and risk/reward systems, and current DoD initiatives to develop a technology investment strategy must overcome many planning, structural, and linkage shortcomings.

Unified "Strategies" and Guidance Just Being Initiated. Investment strategies have been initiated. However, there are major elements of weakness in the

current DoD S&T investment strategy and planning process. There are currently two versions of a DoD S&T investment strategy (one published in June 1990 but not released) and a more recent Defense Technology Strategy and Action Plan (DTSAP). The existence within DoD of two investment strategy planning processes leads to the observation that no stable unified process exists. The more mature strategy was published in June 1990 but to date has not been approved and distributed. This strategy utilized a process involving active participation by the Services & DNA followed by DARPA. The final coordinated product reflects the status quo but is an excellent first step toward establishing a process for a DoD investment strategy. The less mature and more recent strategy was published as an "action plan" in rough draft. The "action plan" was developed without Service participation and incorporated, without clear rationalization, major portions of the June 1990 investment strategy. **The existence within DoD of two separate "processes" leading to separate strategies of widely varying substance, clearly lead one to conclude that there is no stable unified process within DoD for developing an investment strategy and the current efforts have led to fragmented strategies and guidance.**

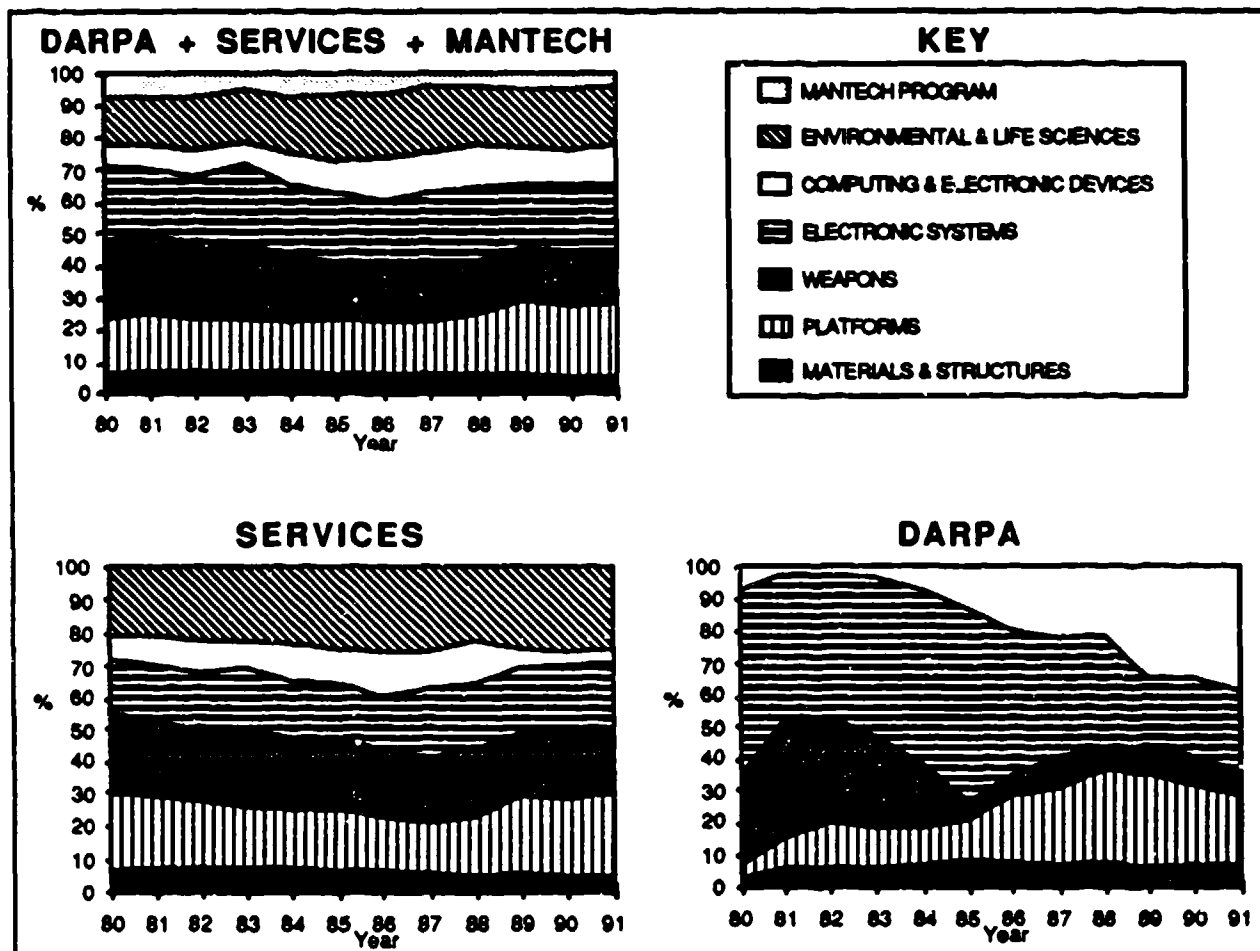
A single stable process must be implemented within DoD. Most importantly, leadership at the top is required to institute a stabilized process. Until we do this, no overarching rationale for the allocation of resources within the DoD S&T program will exist, and this absence is a deterrent to achieving adequate budget stability. Inasmuch as S&T programs are conducted by the three Military Departments and three Defense Agencies, it is obvious that developing a unified strategy will be a continuing challenge. DARPA, SDI & special programs should be full partners in the process (the Services represent less than half of DoD S&T investment in FY91). The challenge is made greater by the tendency of the Congress to make adjustments to the S&T program uncontested by DoD, if there is even the appearance of overlap, duplication, lack of focus, or lack of emphasis.

Missing Links Between Scenarios, Military Capabilities, Technology Goals, and Investments. Current investment strategies do not establish linkage between future scenarios, future military capabilities, future technology goals, and future investments. Top-down rationale and guidance is essential if a bottom line resource allocation is to be correct. The rationale for distribution of S&T resources among the various technical areas has never been articulated and, at best, is only

implicit in the suballocations within the separate S&T programs of the Military Departments and the Defense Agencies. The lack of such a rationale contributes to a lack of understanding of the S&T program within OSD, the Military Departments, the Defense Agencies and the Congress, and invites an amount of program and budget manipulation which is inconsistent with a well-focused S&T program. Neither of the two DoD investment strategies establish linkage among future scenarios, military capabilities, technology goals, and future investments. The prevailing theme that changing times will lead to new/revised warfighting scenarios forces one to conclude that not all of our military capabilities are correct and that some fine tuning will be required and even major surgery could result. But mechanisms are not in place for defining and implementing such changes. Figure 2-1 depicts the funding trends for DoD's S&T investments over the last thirty years. As can be seen, the Services and DARPA have changed in their funding priorities over this period; however, the aggregate DoD investments have been fairly stable. The linkage of actual S&T investments with future scenarios is not obvious.

The necessary commitment to long-term S&T goals is made even more difficult by the combination of short-term fluctuations in perceived user needs and the ease with which significant funding adjustments can be made unilaterally by the Services and Agencies. It is axiomatic that a successful S&T program must have the flexibility to respond to the needs of different users, and this is a primary consideration in the formulation of the programs of the Military Departments. However, perceived user needs vary rapidly when measured on the S&T time scale. Consequently, there has been a reluctance to commit to focussed, long-term goals so essential to an effective S&T program, for fear that the resources will be lost in the cyclic variations in perceived user needs. This reluctance is reinforced by the relative ease with which funding adjustments below the Congressional reprogramming threshold (\$4 million) can be made within the Military Departments and Agencies. (It should be noted that the emphasis here is on efforts focussed on goals, as opposed to efforts devoted to various technology areas. It is easy to see that the S&T program should devote continuing efforts in areas such as high-temperature materials, man/machine interfaces, electronic devices, and the like; however, without the guidance provided by long-term goals, these efforts tend to be diffuse and underproductive.)

**Figure 2-1
Total Distribution of 6.2 and 6.3A Funding by Technology Areas**



Lack of Accountability, Measurement and Rewards at All Levels. Accountability, performance measurement and evaluation, and a reward system are issues that must be addressed and adequately (fairly) resolved by a successful investment strategy and process. The current DoD strategies are very weak in these areas and their credibility will eventually be challenged based on these weaknesses alone. Given the many management/leadership levels within DoD, each with differing systems for evaluating and rewarding performance, the task to achieve a fair and workable set of metrics and rewards could easily become "too hard". Establishing accountability is the necessary first step towards dealing with the more difficult issues of measurement and reward.

Poor Visibility of Both Input and Output. The current program elements/project structure used within the DoD Science and Technology program does not provide ready

visibility into the allocation of resources to either aggregate technology areas (e.g., materials and structures, electronic warfare, aerospace propulsion) or critical technologies. For example, with regard to the DoD list of critical technologies the average number of critical technology efforts imbedded in a program element is about 5.5, and 11 program elements have efforts involving 10 or more critical technologies (see Figure 2-2). Looked at another way, to find the total resources devoted to one critical technology, it is necessary on the average to locate the applicable portions of 30 different program elements (see Figure 2-3). A budgeting and accounting system with these characteristics makes it exceedingly difficult to ascertain technology investments in any meaningful way. In addition, the diffuse nature of the program elements invites adjustments by comptrollers and the Congress which can not be easily related to the impact on specific technology programs, and which create instability in these programs. Because of the difficulty in tracking input, the output in particular technology aggregate or critical technology efforts is difficult to relate to the investment made. Consequently, there is a tendency not to emphasize performance measurement to the degree necessary to ensure efficient programs and appropriate resource allocation.

Figure 2-2
Number of Critical Technologies within Program Elements

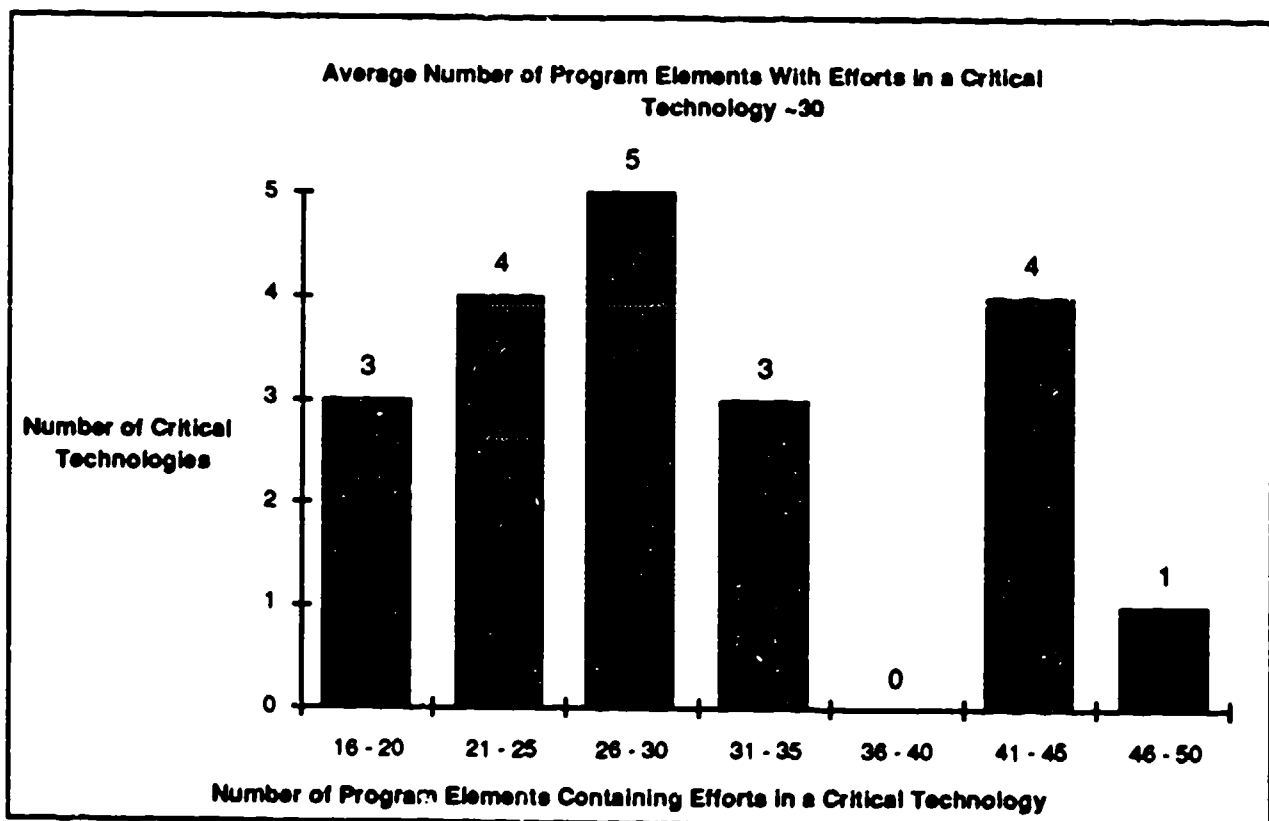
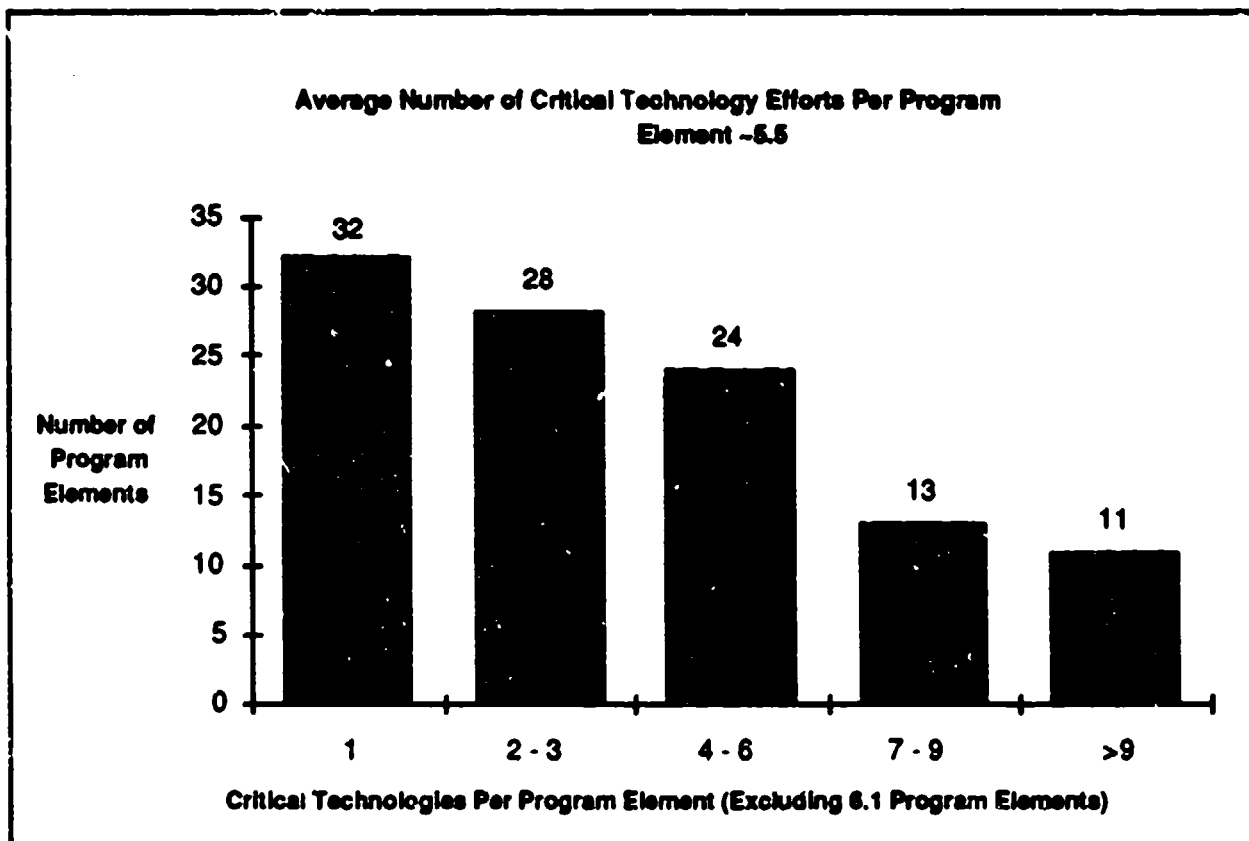


Figure 2-3
Distribution of Critical Technologies over Program Elements



Under-Investment in Process Technology. Considerable guidance exists to support increasing the DoD investment in manufacturing process technology. This may be the only "silver bullet" that re-allocation of DoD Science and Technology (S&T) investments can offer in the near future. Major segments of US industry are investing over 35% of their S&T budget in process technology with claims that US competitors in Japan are investing over 65% of their S&T budgets. Near term increases in profitability can be directly linked to improvements in process technology. The nagging question for DoD is "what are the process technologies in which DoD should invest?" Any DoD investment must be directly linked to future industry manufacturing processes to insure technology transfer.

Critical Defense Industries and Leveraging the Commercial Base Not Addressed. Continued erosion of defense "critical industries" and whole industry segments is expected to accelerate as funding for defense RDT&E and production declines over the coming years. "Critical Industries" are considered essential to

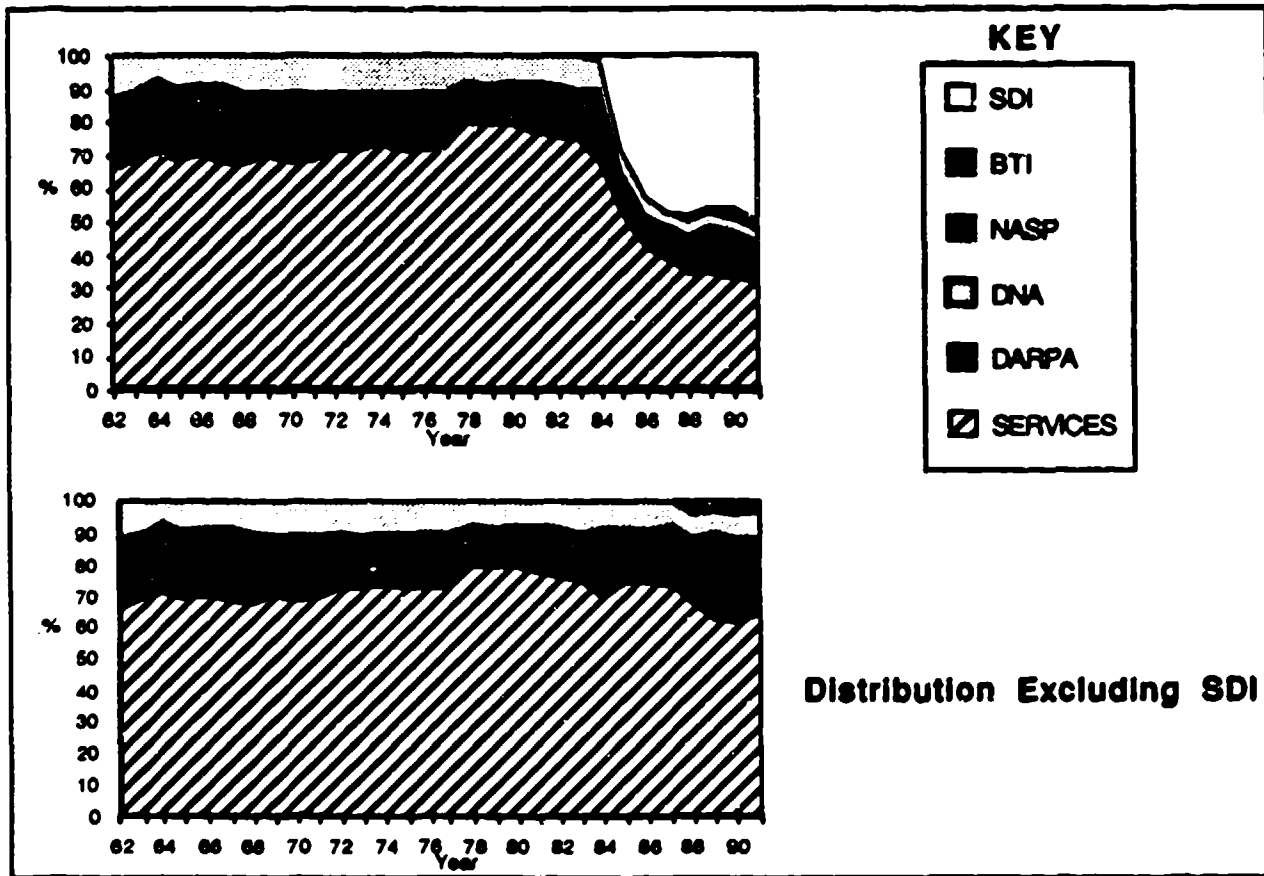
national security needs. The DoD has no structured approach to deal with this problem. The potential for the DoD investment strategy to leverage the commercial industrial base is so great that this issue must be addressed.

Importance and Unique Characteristics of S&T Program not reflected in OSD Management. The DoD S&T program (i.e., 6.1, 6.2, and 6.3A), in providing the foundation for all future military capability, has always been critical to national defense. In the coming era of downsizing, the S&T program will become even more critical in also providing the flexibility to deal with a higher level of uncertainty. Further, the S&T program has some unique characteristics, arising from the necessary diversity of the efforts, the number of DoD Components involved, and the relatively small funding involved. It is important that the management of the S&T program within OSD reflect both the importance of the S&T program and its unique characteristics. We find that the current OSD management of S&T does not adequately reflect either of these imperatives.

Currently, major elements of the S&T program report to three different levels within OSD: the S&T programs of the Military Departments, though largely independent, report through the DDDR&E (Research and Advanced Technology); those of the Defense Agencies through the DDR&E; and those of SDIO directly to the Secretary of Defense. By way of contrast, it would be unthinkable to have different elements of a major acquisition program, such as the Trident, reporting in such a manner.

Obviously, there is no single individual within OSD in charge of the S&T program. In this situation, it is unlikely that the need for the development and execution of a single, unified technology investment strategy can be fulfilled. It should also be noted that, as shown in Figure 2-4, the distribution of the S&T program has changed dramatically in the last decade; in 1980, approximately 80% of the S&T program was in the Military Departments and less than 20% in the Defense Agencies. Even excluding SDIO funding, less than 65% of the S&T program was in the Military Departments in Fiscal Year 1989. Thus the need within OSD for a single individual in charge of the S&T program is even greater today.

**Figure 2-4
Distribution of S&T Funding**



We also find that in the words of the Packard Commission "strong centralized policies that are rigidly adhered to" are still needed for the management of the S&T program. There is no policy which requires an integrated set of goals, strategies, and priorities for the overall DoD S&T program, nor is there a practical mechanism to ensure consistent resource allocations. Two unique characteristics of the S&T program make this need particularly acute.

First, the majority of the S&T program consists of efforts which are difficult to identify as unique to a specific ultimate application for a specific Military Department, and are therefore of interest to all Military Departments. In practice, this requires a high degree of coordination among S&T efforts. Yet each DoD Component prefers to conduct independent S&T programs and to retain complete flexibility to adjust budgets and priorities. Although some degree project selection independence is desirable, the current degree of independence (nearly total) is not possible if a unified technology

investment strategy is to be executed. We note that this situation is in marked contrast to that generally prevailing in system development, wherein the programs are usually unique to a Military Department and can be efficiently conducted in an independent manner (and, even here, OSD review and approval is still essential for integration into a total plan).

Second, relatively small funding changes--say, of the order of \$5 million-- in an S&T effort can have an enormous impact, because such a change will typically represent 10% or more of total program element funding and because the prevalence of controlling annual growth in each S&T program element ("ramp management") will tend to perpetuate the same percentage adjustments to future years. Changes of this magnitude are currently well below the threshold of formal OSD consideration, with the result that there is no effective overall control of resource allocation in the S&T program. This has left the S&T program vulnerable to "raiding" by the Military Departments to pay for unforeseen obligations (e.g., overruns on major acquisition programs), as well as adjustments with significant impact by both the Comptroller and the Congress. The absence of substantial S&T funding growth during the large RDT&E growth of the 1980's provides partial evidence of this lack of control, and of the need for a stronger advocacy position.

These difficulties in OSD management are not new, but in our view, they have increased substantially in the last decade. For example, in 1980, a staff-originated action concerning the S&T program would pass through one intermediate office before reaching the Under Secretary level; in 1990, this same action must pass through four intermediate offices before reaching the Under Secretary level. Simultaneously, the authority and clout of one of the intermediate offices - the DDR&E - has been eroded. The consequences for proper OSD management of the S&T program are painfully clear.

2.2 CRITICAL TECHNOLOGIES

2.2.1 INTRODUCTION

The Task Force was tasked to identify technologies critical to DoD in the coming years. In preparation for this assessment, the Task Force reviewed current DoD efforts to identify critical defense technologies. This review included:

- The Defense Critical Technologies Plan (DCTP) compiled at the request of Congress
- The Defense Technology Strategy and Action Plan (DTSAP), developed by DDR&E, and
- A list of technologies compiled by DARPA.

The Task Force found that the DCTP and DARPA listings described in a comprehensive way several technologies important to national security and the opportunities offered by these technologies to meet military requirements. The DTSAP went much further by defining strategies and the interrelationships among required capabilities, strategies, objectives and critical technologies.

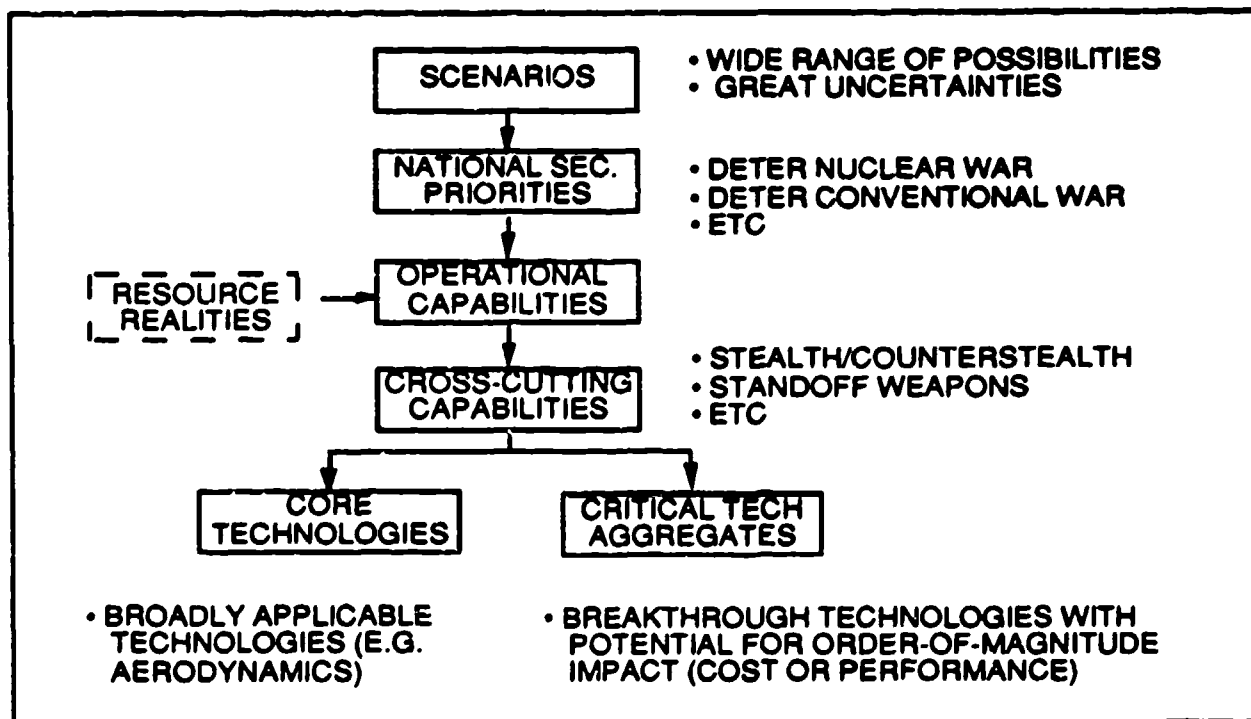
The Task Force was not satisfied with the methodologies employed by any of the above efforts. The group reviewed several other approaches and selected a scenario-based methodology as the best for identifying and prioritizing those technologies that are critical to the future national security objectives of the United States (see Figure 2-5). This methodology was then employed by the Task Force.

Scenario-based technology assessment consists of the following sequential steps (which are amplified -- with specific examples -- in Appendix D):

- A. Establish a mutable set of scenarios which represent a wide range of potential futures, but which also recognize great uncertainties;
- B. Derive from those scenarios a set of national security priorities, e.g. deter nuclear war, deter conventional war, etc. (As a practical matter the panel adopted the President's "National Security Strategy of the United States" as the conceptual backdrop for subsequent steps in the process.);
- C. Compare national security priorities with current operational capabilities to identify relative "overshoots" and "undershoots";
- D. Match operational capabilities against resource realities and identify those cross-cutting capabilities essential to more than one set of operational capabilities that have especially high leverage (stealth, counter-stealth, standoff weapons, etc.);

E. Devolve the cross-cutting capabilities into *technology aggregates*. Then, sort out both critical technology aggregates that portend order-of-magnitude impact (in either cost or performance) and essential core technologies which have broad applicability and are essential to operations of the forces.

**Figure 2-5
Scenario-Derived Critical Technologies**



Appendices D and E provide the detailed assessment prepared by this Task Force.

- Critical Technology aggregates are groupings of technologies which, when taken together, offer significant military payoff, far more than when viewed as individual technologies.

2.2.2 IDENTIFICATION OF CRITICAL TECHNOLOGIES

The Task Force evaluation of the full breadth of possible future scenarios and needed operational capabilities identifies a number of cross-cutting military capabilities that are common to many of the scenarios and which are critical to accomplishment of US objectives. Examples of these cross-cutting military capabilities are shown in Figure 2-6.

**Figure 2-6
Some Cross-Cutting Military Capabilities**

- | | |
|--|---|
| • Precision Standoff and Counter-standoff Weapons | • Real-Time Command Management Systems (Data → Information) |
| • Stealth & Counter-Stealth | • Antijam, Covert Communications |
| • Robust Automatic Target Recognition and Identification | • Active Countering of Enemy Target Acquisition Systems (ECM, ASAT) |
| • Brilliant Systems | • Rapid Response Long-Range Lift for Force Projection |
| • Assured Access to Space | • Lightweight, High-Firepower, Minimally-Manned, Survivable Forces |
| • Night/All-Weather Capability | |

For example, because our interests are world-wide and we are not likely to have bases in all of the regions of the world where US interests may be challenged, space systems will become increasingly important. Space systems can provide worldwide, real-time surveillance to assess the situation. Once military action is deemed necessary, space systems can provide the communications, surveillance, and targeting to lightweight, high-firepower, minimally-manned, survivable forces projected into the region by our rapid-response, long-range lift capability. Because these space systems are potentially so critical to US operations, we must maintain assured access to space and insure that the capabilities provided by our systems there are protected against projected enemy anti-satellite capabilities.

Because our active forces are likely to be smaller, we must provide them with the technological advantage to survive and prevail against an increasingly technically sophisticated adversary. This includes operating in a situation where stealth may be critical for penetrating enemy defenses and counter stealth capability may be required for timely engagement of enemy threats (e.g., stealthy, sea-skimming missiles that threaten surface ships).

Because potential conflicts will require the use of lightweight, high-firepower, minimally-manned forces, we will need systems which greatly enhance the capability of our forces to find and negate targets quickly, including at night and in all-weather conditions. Thus, real-time command management systems, automatic target recognition and identification systems and the ability to detect targets which are concealed or camouflaged are important to finding and engaging enemy targets. Brilliant autonomous weapon systems and precision standoff weapons will allow our forces to engage the enemy efficiently while minimizing risk if our forces are outnumbered.

The technology aggregates identified by the Task Force using its methodology are shown in Figure 2-7 and described in Appendix D. As shown, these aggregates are subdivided into critical technology candidates and core technology candidates, on the basis of the the following definitions:

- ***Core Technology:*** technologies which are needed to maintain, strengthen, or establish a continuing competence or capability. Core technologies are the foundation for:
 - sustaining technological competencies; and
 - making significant, but evolutionary improvements in warfighting capabilities
 - supporting revolutionary innovations
- ***Critical Technology:*** candidate technologies must meet all of the following criteria:
 - provide a significant leap forward in warfighting advantage (in both quality and quantity)
 - have a high entry barrier (no reasonable substitutes)
 - have a relatively long transfer time to controlled countries (greater than three years).

Some of these technology aggregates are uniquely military, at least at the systems level, and do not normally benefit from the national civilian technology base for dual-use technologies. These technologies must be given special consideration in developing an investment strategy, since the DoD must assume total responsibility for their development and reduction to practice. For those technologies that are not uniquely military, DoD must establish mechanisms which effectively leverage commercial developments.

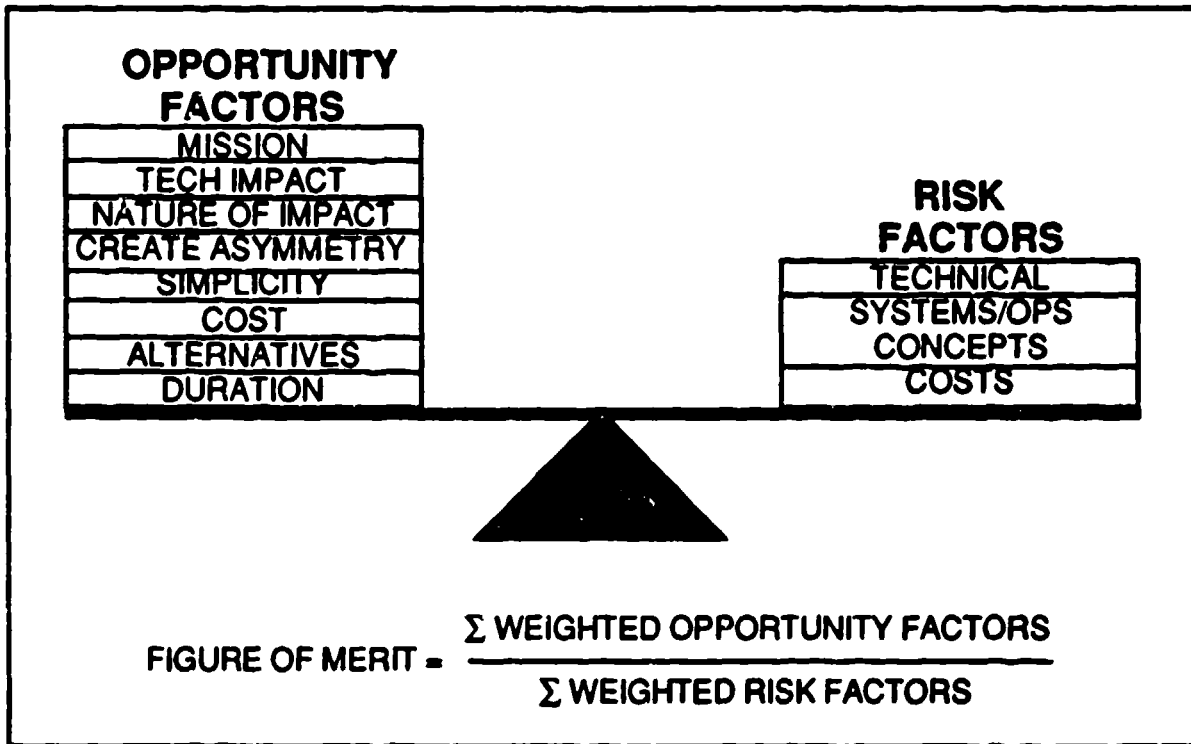
**Figure 2-7
Technology Aggregates**

CRITICAL TECHNOLOGY CANDIDATES	
1.	INTEGRATED CIRCUITS (DIGITAL, ANALOG, MICROWAVE)
2.	ADVANCED SOFTWARE
3.	IR FOCAL PLANES (SPACE SURV/TACTICAL TARGETING)
4.	LOW VOLUME FLEXIBLE MANUFACTURING
5.	AUTOMATIC TARGET RECOG (SIGNAL UNDERSTANDING)
6.	COUNTER STEALTH (DIGITAL RADAR)
7.	STEALTH TECHNOLOGY
8.	SIMULATION/MODELING/TRAINING
9.	SIMULTANEOUS ENGINEERING
10.	BRILLIANT SYSTEMS
11.	HYPERMEDIA INFORMATION MANAGEMENT
12.	SATELLITE SURVIVABILITY
13.	ANTI-SENSOR WEAPONS
14.	PHOTONICS
15.	HYPERSOUND KINETIC WEAPONS
16.	ADVANCED ROCKET PROPULSION
17.	DIRECTED ENERGY WEAPONS
18.	HIGH ENERGY - DENSITY MUNITIONS
CORE TECHNOLOGY CANDIDATES	
1.	AIR-BREATHING PROPULSION
2.	SIGNAL PROCESSING
3.	DATA FUSION
4.	FLUID DYNAMICS
5.	SOFTWARE ENGINEERING
6.	ACOUSTIC DETECTION
7.	MICROWAVE TUBES
8.	COMPOSITE MATERIALS
9.	CONVENTIONAL ARMOR AND ANTI-ARMOR
10.	CHEMICAL ROCKET PROPULSION
11.	NUCLEAR TECHNOLOGY

2.2.3 PRIORITIZATION OF TECHNOLOGIES

Since the opportunities for doing important research and development on technologies will almost certainly exceed available resources, a prioritization mechanism is needed for the development of an investment strategy. A methodology that includes an assessment of both opportunities and risks in the ranking of technologies, developed and recommended in the 1981 DSB Summer Study, was found to be of great value. The rating factors for this methodology are shown in Figures 2-8 and 2-9.

**Figure 2-8
Technology Assessment Methodology**

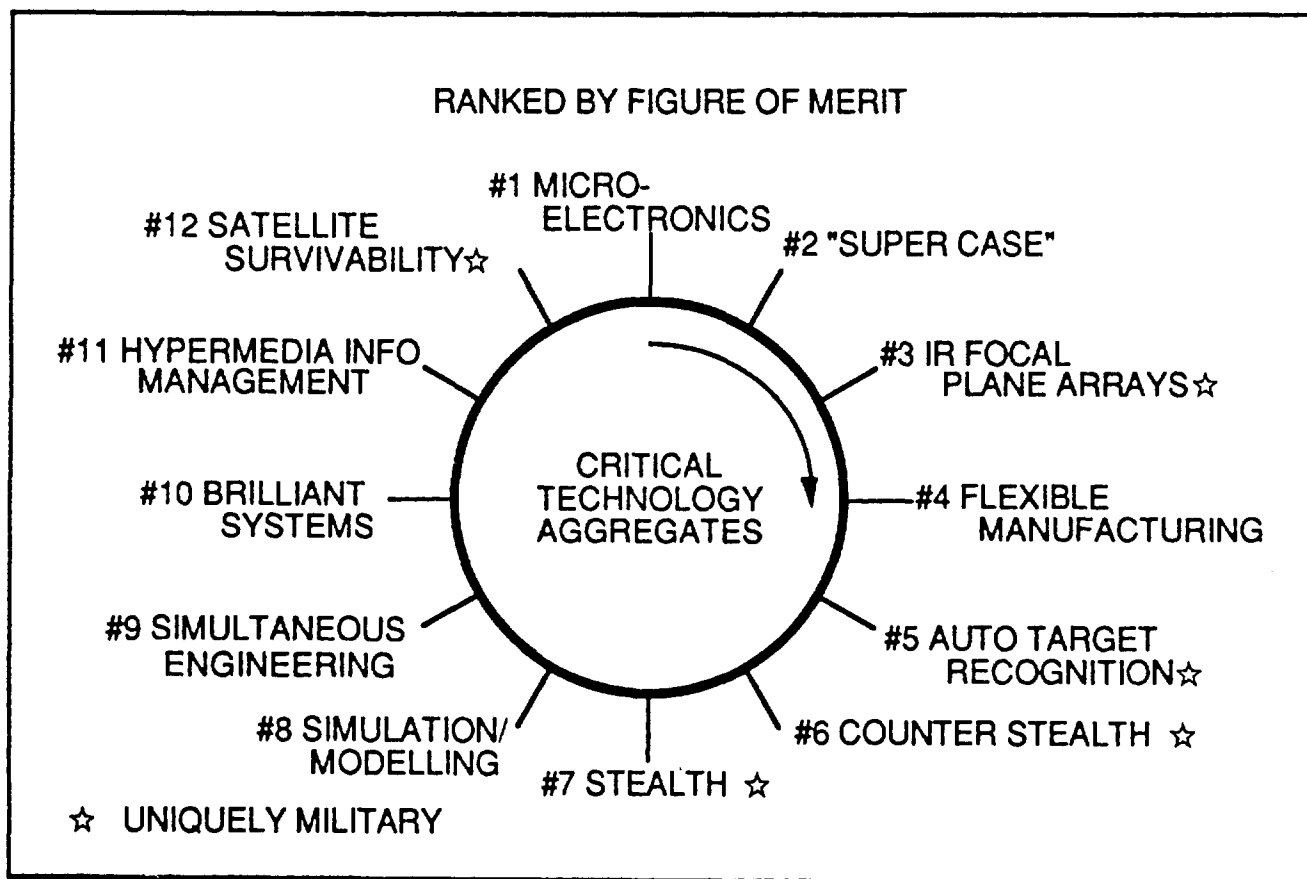


**Figure 2-9
Technology Assessment Criteria**

	HIGH (3PTS)-GREEN	MED (2PTS)	LOW (1PTS)-RED	
A. IMPACT OR OPPORTUNITY	1. MISSION VALUE	STRATEGIC NUCLEAR (OFFENSE AND DEFENSE), SPACE	TACTICAL NUCLEAR TACTICAL CONVENTIONAL	GENERAL SUPPORT AND LOGISTICS
	2. TECH-IMPACT ON MISSION/SYSTEM	RAISON 'D' ETRE - SYSTEM WOULD NOT EXIST W/O THIS PARTICULAR TECHNOLOGY, ORDER OF MAGNITUDE IMPROVEMENT	TECHNOLOGY SIGNIFICANTLY AFFECTS PERFORMANCE	GENERALLY AFFECTS PERFORMANCE
	3. Pervasiveness	ACROSS MANY MISSIONS AND SYSTEMS	SUPPORTS ONE MISSION OR CLASS OF SYSTEMS	SPECIFIC TO ONE OR A FEW SYSTEMS
	4. NATURE OF IMPACT	REVOLUTIONARY	SIGNIFICANT CHANGE	EVOLUTIONARY
	5. LEVERAGE (EXPLOITS US/SSR ASYMMETRY)	GIVES CAPABILITY TO REDRESS SHORT TERM IMBALANCE (E.G., A PRESENT OR PROJECTED SYSTEM)	REDRESSES LONG TERM IMBALANCES	US/SSR FORCE STRUCTURES ARE COMPATIBLE IN SIZE AND SOPHISTICATION FOR NOW AND FUTURE
	6. SIMPLICITY	COULD RADICALLY SIMPLIFY WEAPONS	MODERATE INFLUENCE	LITTLE IMPACT
	7. COST	COULD RADICALLY REDUCE COST	MODERATE INFLUENCE	LITTLE IMPACT
	8. EXISTENCE OF ALTERNATIVES	NO VIABLE ALTERNATIVES	BRUTE FORCE COULD CREATE AN ALTERNATIVE	ONE OR MORE EXISTS
	9. DURATION OF IMPACT	A LOWER IN COST COULD EXIST IN > 10 YEARS	IN < 10 YEARS	IN < 5 YEARS
B. TECHNICAL RISKS	1. MATURITY OF TECHNOLOGY	APPLICATION UNCERTAIN, EMERGING	STILL DEVELOPING	MATURE TECHNOLOGY
	2. TECHNOLOGY BASE	A "GAP" EXISTS; REQUIRES NEW KNOWLEDGE BASE	A "GAP" EXISTS; BUILDS ON CURRENT KNOWLEDGE BASE	PRINCIPAL TECHNOLOGIES ARE PRACTICED IN DoD COMMUNITY
	3. INNOVATION POTENTIAL	DoD \$\$\$ ADD LITTLE SINCE THIS IS AN AREA OF STRONG TECHNOLOGY COMPETITION	MORE EVOLUTIONARY IN NATURE	DoD APPROACH PROVIDES A SIGNIFICANT PERFORMANCE ADVANTAGE
C. SYSTEM/ OPERATIONAL CONCEPT RISKS	1. MISSION/SYSTEM RELATED RISKS	SYSTEM CONCEPT NOT IN EXISTENCE TODAY	REQUIRES EXTENSIVE APPLICATION SUPPORT, NEW SYSTEM/CONCEPT TO DoD BUT WHICH IS IN EXISTENCE	SIMILAR CONCEPTS OR SYSTEMS TO CURRENT DoD
	2. POLITICAL BUREAUCRATIC ENVIRONMENT	DEPENDENT ON ASSETS CONTROLLED BY EXTENSIVE INFRASTRUCTURE, REQUIRES CHANGE IN ARMS CONTROL AGREEMENT	REQUIRES REPLACEMENT OF MATURE TECH OR CREATION OF AS YET UNPERCEIVED NEEDS	REQUIRES EXTENSION OF EXISTING SYSTEM TREATIES/ INFRASTRUCTURE
	3. LEVEL OF OPERATIONAL/ SUPPORT IMPACT	REQUIRES SIGNIFICANT SHIFT IN PERSONNEL AND IN SUPPORT INFRASTRUCTURE	REQUIRES SOME UNIQUE SKILLS/ SUPPORT	CAN TAP AVAILABLE PERSONNEL AND /OR SUPPORT
D. R&D COSTS	1. MANUFACTURING BASE	CAPITAL INTENSIVE AND REQUIRES SIGNIFICANT \$\$\$ EXPENDITURES; KEY PROCESSES MUST BE DEVELOPED	REQUIRES UNIQUE FACILITY; PROCESSES/ EQUIPMENT KNOW TO EXIST	BUILDS ON AVAILABLE BASE
	2. UNIQUENESS OF MILITARY AID	UNIQUELY MILITARY, HIGH R&D COST TO DoD	SELECTED ASPECTS OF TECHNOLOGY ARE UNIQUELY MILITARY	PRIMARILY COMMERCIAL, DoD EXPLOITS COMMERCIAL DEVELOPMENTS
E. SUMMARY	ORDER OF MAGNITUDE IMPACT LOWER RISK; OPPORTUNITIES TENDING TOWARD GREEN	MIXED	IMPACT UNCLEAR/EMERGING A. NOT CLEARLY RED B.C.D. TENDING TOWARD RED	

This rating system has been applied to the critical technologies identified by the panel, and the results of the ratings for the critical technologies are shown in Figure 2-10. The technologies are displayed in rank order by figure of merit, defined in Figure 2-8 as the summed opportunity factors (weighted) divided by the summed risk factors (weighted). A sample evaluation sheet for infrared focal planes (including weighting factors) is shown in Figure 2-11. Appendix E contains the full set of technology ratings and a more detailed discussion of the numerical rating process.

Figure 2-10
Critical Technology Aggregates



**Figure 2-11
Infrared Focal Planes**

<u>WT</u>	<u>IMPACT OR OPPORTUNITY</u>	
2.5	Mission Value	3
2.0	Technical Impact on Mission/System	3
1.5	Pervasiveness	3
2.0	Nature of Impact	2
2.0	Leverage (Exploits Enemy Asymmetry)	3
1.5	Simplicity	1
2.0	Cost	1
2.5	Existence of Alternatives	2
1.5	Duration of Impact	2
<u>WT</u>	<u>RISK FACTORS</u>	
	Technical Risks	
2.0	• Maturity of Technology	2
1.5	• Technology Base	2
2.5	• Innovation Potential	1
	System/Operational Concept Risks	
2.0	• Mission/Systems Related Risks	2
2.5	• Political Bureaucratic Environment	1
2.5	• Level of Operational Support Impact	2
	R&D Costs	
2.0	• Manufacturing Base	2
2.0	• Uniqueness of Military R&D	2
		Rating*
	Opportunity Rating	95 High
	Risk Rating	60 Med
	Technology Figures of Merit	1.583
	*High (88-140)	
	Med (56-87)	
	Low (35-55)	

Although the Task Force focused primarily on selecting critical technologies with order-of-magnitude impact, it was clear that a DoD investment strategy must give attention to investments in both critical and core technologies. That is, investments in potential order-of-magnitude improvement in future military capabilities must be complemented by investments in strengthening current military capabilities. Also,

revolutionary technological developments must be complemented by evolutionary developments.

Additional insight can be obtained by displaying the critical technology aggregates and the core technologies in a matrix of opportunity versus risk. This is shown in Figure 2-12. (Consistent with the Task Force emphasis on critical technologies, the assessment of opportunity and risk for selected core technologies is only qualitative). This mapping highlights the differences between the two classes of technology which are important to DoD. Most critical technologies aggregates mapped into those segments of the matrix representing:

- exceptional opportunity - medium risk (example - Integrated Circuits)
- exceptional opportunity - high risk (example - Directed Energy Weapons)
- significant opportunity - low risk (example - Automatic Target Recognition)
- significant opportunity - medium risk (example - Counter stealth)

No critical technology aggregates ranked lower than significant opportunity or in segments designated exceptional opportunity - low risk or significant opportunity - high risk, as might be expected.

Core technologies tended to rank in segments representing:

- significant opportunity - low risk (example - Microwave Tubes)
- modest opportunity - low risk (example - Air-Breathing Propulsion)
- modest opportunity - medium risk (example - Chemical Rocket Propulsion)

Obviously, application of the methodology recommended here involves several judgments, and different groups will undoubtedly arrive at somewhat different rankings. Such differences will be small, and we recommend the use of this methodology on the basis of its three strongest attributes: it will identify emerging critical technologies (we believe, for example, that it would have identified stealth technology as a critical technology in the mid-1970's); it considers risks as well as opportunities; and it provides an explicit framework for evaluating the significant factors in determining the eventual military value of technologies.

**Figure 2-12
Opportunity/Risk Assessment**

OPPORTUNITY	EXCEPTIONAL		<ul style="list-style-type: none"> • INTEGRATED CIRCUITS • IR FOCAL PLANES • BRILLIANT SYSTEMS • ANTI-SENSOR WPN 	<ul style="list-style-type: none"> • HI ENERGY-DENSITY MUNITIONS (>10xHE) • DIRECTED ENERGY WEAPONS
	SIGNIFICANT	<ul style="list-style-type: none"> • "SUPER" CASE • FLEXIBLE MANUFACTURING • AUTO TARGET RECOGNITION • SIMULTANEOUS ENG • HYPERMEDIA INFO • <u>Microwave Tubes</u> • <u>Signal Processing</u> • <u>Acoustic Detection</u> 	<ul style="list-style-type: none"> • COUNTERSTEALTH • STEALTH • SIMULATION/MODELING • SATELLITE SURVIVABILITY • HYPERVELOCITY KEW • PHOTONICS • ADV ROCKET PROP 	
	MODEST	<ul style="list-style-type: none"> • <u>Air Breathing Propulsion</u> 	<ul style="list-style-type: none"> • <u>Chem Rocket Propulsion</u> • <u>Conventional Armor/Anti-armor</u> 	
		LOW	MEDIUM	HIGH
		RISK		

KEY: - Core Technologies.

• **CRITICAL TECHNOLOGIES**

The quantification of payoff and risks associated with possible technology investments can provide an important input to an investment strategy. It is crucial to be aware that a balanced technology program cannot consist of critical technologies alone. It must include core technologies and "bottom-up" R&D programs that offer promise of providing new technology "seeds". While the Task Force finds that the DoD has traditionally supported core technologies and "seed" R&D programs, critical technologies, such as those derived from scenario-based planning, require greater emphasis. The Task Force recommends that such planning be used as a basis for developing both an investment strategy and action plan that will give greater focus to the current S&T program and that will reflect priorities and future, high-leverage returns on investment.

The Task Force compared its selections of critical technology aggregates with those identified in the Defense Critical Technology Plan (DCTP). This comparison is shown in Figure 2-13. The panel found that 12 of the DCTP critical technologies were in general agreement with those critical technology aggregates identified by the DSB-proposed methodology.

The panel also found that six of the DCTP "critical" technologies satisfied the panel's criteria for core technologies. Two of the DCTP "critical" technologies (superconductivity, and biotechnology materials and processes) satisfied neither criteria for a core technology or critical technology aggregate because they are in too early a state of development. They are worthy of funding now in the "seed" R&D technology driven portion of the program and could well emerge as critical technologies in a few years given continued progress and insight. They are designated "emerging technologies".

**Figure 2-13
Comparison with Critical Technologies Plan**

<p>CRITICAL TECHNOLOGIES: SIGNAL PROCESSING (AUTOMATIC TARGET RECOGNITION) SEMICONDUCTOR MATERIALS AND INTEGRATED CIRCUITS (INTEGRATED CIRCUITS) SOFTWARE PRODUCTIBILITY (ADVANCED SOFTWARE - CASE) PARALLEL COMPUTER ARCHITECTURE (HYPERMEDIA INFORMATION MANAGEMENT) PASSIVE SENSORS (IR FOCAL PLANES) SENSITIVE RADARS (COUNTER-STEALTH) SIMULATION AND MODELING (SIMULATION/MODELING/TRAINING) PHOTONICS (PHOTONICS) SIGNATURE CONTROL (STEALTH TECHNOLOGY) HYPERVELOCITY PROJECTILES (HYPERVELOCITY KEW) PULSED POWER (DIRECTED ENERGY WEAPONS) HIGH ENERGY-DENSITY MATERIALS (HEDM - >10 x HE)</p>
<p>CORE TECHNOLOGIES: DATA FUSION COMPOSITE MATERIALS AIR-BREATHING PROPULSION WEAPON SYSTEM ENVIRONMENT COMPUTATIONAL FLUID DYNAMICS MACHINE INTELLIGENCE & ROBOTICS</p>
<p>EMERGING TECHNOLOGIES: SUPERCONDUCTIVITY BIOTECHNOLOGY MATERIALS AND PROCESSES</p>

KEY: (...) - DSB TASK FORCE RECOMMENDATIONS

Although there was a good deal of consistency between the list of technologies created by this Task Force and the DCTP, the Task Force recommends that DoD employ a more structured methodology (such as the one used by this effort) in future efforts. The Task Force concluded that in the next round of critical technology selection, the process employed must be capable of giving stronger emphasis to:

- An assessment of technological opportunities versus risks
- The identification of "Critical" technologies as well as "Core" technologies
- Process and manufacturing technologies
- Potential "Order of Magnitude" improvements

- Technological surprise and paradigm shifts
- Explicit connection between technology milestones and military worth
- Strengthening the link between critical and core technologies and DoD resource allocation, and
- More focused attention on certain technologies now embedded in the DoD list but which are not highlighted, (e.g. low-volume, flexible manufacturing, microwave tubes, and simultaneous engineering).

2.2.4 PROCESS AND MANUFACTURING TECHNOLOGIES

In its evaluation of critical and core technologies, the Task Force found that DoD needs, but has yet to develop, an investment philosophy for process and manufacturing technologies that is geared to more rapidly producing lower-cost, higher-quality, more-reliable defense hardware in the face of declining defense budgets. A number of the critical and core technologies require DoD investment in process and manufacturing technologies. The Task Force found that DoD RDT&E expenditures have been predominantly focused on product-developments; line-item investments in process and manufacturing technologies have generally been less than one percent of total expenditures (approx. \$350 M in FY90) and probably less than 5% overall (there has never been a detailed analysis). This is in stark contrast to estimated investment ratios (process/product) for highly-developed countries, e.g. approximately 2:1 for Japan, 1:1 for Europe, and 1:2 for the US. Some Fortune 100 US companies invest 30% or more in process and manufacturing technologies. The results of a traditional under-investment in these technologies by the DoD in the face of increasing technological complexity have been unacceptable quality, excessive rework, uncertain reliability and escalating unit costs. A philosophy is urgently needed by the DoD upon which to derive technology strategies, high-leverage programs and increased contractor investments.

Manufacturing capability is defined by:

- equipment, tools and fixtures,
- process "recipes" (process design rules and specifications),
- training and human resource utilization, and
- process flows, i.e. the collection of process recipes used in manufacturing.

It is the integration of these elements into a total manufacturing system, to include information and total quality management systems, that comprise the manufacturing

enterprise. From a technological point of view, it is the combination of "know how" (accumulated procedural knowledge), capital investment (today's technology), and R&D (tomorrow's technology) that leads to major innovations. Japan's success in winning world markets has largely come through continuing innovations in process and manufacturing technologies, many of which are generated by the work force.

Integrated factory information systems (Factory C³) may be more important than robotics in fostering flexibility and productivity of capital. Factory C³ integrates:

- simulation
- planning
- dynamic scheduling
- material management
- maintenance, diagnostics, prognostics
- process control
- training
- statistical process control
- testing and quality control

Such information systems, if fully integrated, can have the effect of empowering the work force, reducing indirect labor and layers of supervision, facilitating total quality management and just-in-time management, increasing the flexible control of work cells, and enabling the cost-effective manufacture and assembly of low volumes of discrete parts. Therefore, the development and implementation of factory C³ should have the highest priority in DoD investments in process and manufacturing technologies.

The greater enforcement of simultaneous engineering (integrated product design and manufacturing) to cut span time from conceptual design to production and costs should also be given high priority. Simultaneous engineering facilitates design for manufacturability, testability, quality and reliability and enables time-based management in major programs where longer time span equates to higher costs. The discipline of simultaneous engineering should incorporate the following principles for greatest cost effectiveness:

- constrain design to make maximum use of existing plant and equipment;
- provide the necessary tools (computer and software aids) to implement concurrent engineering, i.e. work the data representation and data base issues required to support tool integration;
- integrate total quality management throughout the multi-tier procurement chain to minimize incoming inspection and to reduce "quality appraisal" and "failure" costs; and

- **emphasize flexible manufacturing to minimize material handling and inventory (working capital) costs.**

In addition to these principles, the defense industry should be encouraged to increase R&D investments and motivate, recognize, and reward innovations that result in major reductions in cost and improvements in quality and productivity. Furthermore, current restrictions on the use of IR&D funding for developing new processing and manufacturing technologies should be lifted.

There are other benefits that can have a major impact on reducing manufacturing costs:

- **To the maximum extent practical, the DoD should insist on common equipment among manufacturing lines to facilitate product standardization, rationalization, and interchangeability.**
- **The DoD should maintain a library of process "recipes" (process design rules and process specifications) for parts and assembled hardware in serial production to keep track of learning curves, enable surge production, and support the periodic production of spare parts. As included strategies under this principle:**
 - **process flows should maximize "recipe" reuse**
 - **"recipe" reuse should maximize equipment utilization and returns on capital investment, and**
 - **the "recipe" library should be updated and upgraded by means of IR&D investments.**

These suggested principles can and should be broadened for specific industry segments and are intended to be exemplary. However, a few overriding considerations apply to those defense manufacturing and process facilities which have fallen far behind "world-class" standards because of lack of investment in R&D and modernization. Before investing in the automation of these facilities, process flows should be simplified and investments made in flexible work cells and improved unit operations (prove before improve, and "clean up" before automate). Commercial companies that have by-passed these steps in their hurry to automate have greatly mal-invested and are now facing second-, and even third-round automation. There are abundant case experiences and success stories in the civilian sector to help guide DoD strategies in needed plant modernization and facility upgrades.

2.3 TECHNOLOGY SURPRISE AND PARADIGM SHIFTS

2.3.1 INTRODUCTION

The development of a DoD strategy for long-term development of critical technologies must also ensure that proper attention is focused on anticipating and defending against sudden, unexpected enhancements to an enemy's capabilities. The appearance of such "surprises" can evolve from two different mechanisms, namely:

- Pure Technological Surprises - these arise from a previously unforeseen use of an entirely new technological weapon or threat. Examples of such surprises in the past are atomic bombs used by the U.S against Japan and V2 ballistic missiles used by the Germans against the U.K.
- Tactical and Operational Technological Surprises - these arise not so much from new technology, per se, but from the use of known technologies within different "doctrine and tactics". Examples employing altered "operational strategies" are the use of Blitzkrieg and modern terrorism tactics. Additional examples, that are more technology related, are the incorporation of laser guidance into bombs (in the Vietnam War), and by the use of air-power in the naval environment made possible by the introduction of aircraft carriers (the attack of Pearl Harbor).

The impact created by the sudden appearance of such technology surprises on the battlefield can often go beyond the obvious shift in military balance. Such appearances create confusion and panic in the enemy, particularly when the impression is created that no ready defense against a "strange" weapon is available. In other words, this element of surprise acts as additional leverage on the effectiveness of the technological surprise or paradigm shift.

Tactical and operational technological surprise is generally easier to anticipate than pure technological surprises due to the presence of weak signals. Also, an element of innovation in the case of military use is often related to tactics and doctrine, an area in which military personnel are very knowledgeable. However, military forces cannot be expected to have the level of technical expertise needed to anticipate new technological breakthroughs, which often requires a completely different mind set. For example, a rather sophisticated understanding of quantum physics would have been necessary to anticipate the atomic bomb. Scientists with the necessary sophisticated

knowledge often don't have the background in military strategies to apply the scientific knowledge to military planning.

Because of the above argument regarding the difficulty of anticipating technology surprises, and also because of the accelerating pace of developing new technologies, the potential for the US to be "surprised" in the future is increasing and therefore merits serious analysis.

2.3.2 AREAS OF POTENTIAL TECHNOLOGICAL SURPRISE

To provide some insight into the range of possible technology breakthroughs, the Task Force developed an illustrative list of such technologies (see Figure 2-14). Through a Delphi process, the list was condensed to six technological surprises that the panel felt to be of greatest near-term concern, namely:

1. (Soviet) Laser ASAT - Key ingredients in US global capability for C³I are communications and intelligence-gathering satellites in orbit. It is known that the Soviets have been working on laser technology as a means of neutralizing our satellites. Successful deployment of such a weapon by the Soviets would deny the US a vital capability.
2. Super-Quiet, Non-Nuclear Submarines - The essence of this technology is the deployment of a submarine which is virtually undetectable by existing means. Such a technology would likely employ chemical fuel cells in conjunction with electric drive rather than nuclear power. The sudden reality of such a capability could produce a significant shift in strategic defense postures.
3. "Stealth" Rocket - Such a technology would provide capability for an inter-regional or inter-continental attack with very little early warning. Possession of such a capability by a third-world power could seriously upset regional balance.
4. Code Breaking / "Trap Doors" - These are two distinct but related threats. They derive from the discovery of mathematical principles and/or algorithms which can greatly facilitate the breaking of codes. Such a breakthrough would allow one side to read the other's mail, and would be particularly insidious if the victim does not realize that his codes have been broken.

5. Chemical Warfare Against Vehicles - There continues to be significant effort in chemical weapons, primarily devoted to use against personnel. It is conceivable that non-toxic agents could be developed which would disable equipment rather than personnel, and hence could be used in an unrestricted manner. Weapons of this nature would require significant changes in doctrine, tactics, and equipment.

6. Space-Based Attack Weapons - A small number of weapons parked in orbit around the earth which are capable of precision targeting of selectable targets on earth would be extremely formidable. Essentially any target in the world could be reached with very little delay and with practically no warning.

Figure 2-14
Potential Technological Surprises

(Soviet) Laser ASAT
Super-Quiet Non-Nuclear Submarines
"Stealth" Rocket
Code-Breaking/"Trap-Doors"
Chemical Warfare Against Vehicles
Space Attack Weapon
Robust Automatic Target Recognition
Long-Range Gun-Launched Precision Guided Munitions
Enemy Use of Unmanned Vehicles
Non-Nuclear EMP/EM Weapon
Transparent Ocean
Micro-Robotic Sensors/Weapons
Non-Lethal Area Troop Disabler
Smart Mines
Electronically-Excited High Energy Density Fuels/Explosives
Anti-Sensor Weapons (Lasers)
AI Near Equivalent to Human
Biological Military Systems
Air Base Neutralization
Clean Nukes
Beyond Visual Range Air-to-Air Missiles
War Reserve Frequencies

2.3.3 TECHNOLOGY-DRIVEN POTENTIAL PARADIGM SHIFTS

The Task Force identified a number of examples of technology-driven paradigm shifts which are beginning to occur in today's society and which could have significant impact on DoD. These examples are outlined in Appendix F and selected paradigms are described here.

From Traditional Factory Control to Factory C³ Capabilities. The integration of all activities occurring throughout a factory environment into a coherent and inter-related process can result in more flexibility and lower costs with better quality, even for low-volume production.

From Unenhanced Decision Making to "Intelligent Assistants" (e.g. Pilot's Associate, Commander's Associate). These Artificial Intelligence packages provide the opportunity to significantly improve the correctness of our decision makers by emulating the kind of support that such a decision-maker could expect from a super-intelligent staff.

From Reliance on Human Cognition to Fast-Convergent, Self-Taught Reasoning Systems (Artificial Neural Nets). Most Artificial Intelligence techniques are based on establishing a set of rules for decision-making. Such rules are usually obtained from experts. The advantage of neural network technology is that very little problem structure needs to be defined. Rather the neural network has the capability, through repeated trial and error, to establish its own virtual rules. This technology can therefore deal successfully with very complex problems, particularly those requiring cognitive powers, for which no algorithms are available.

From Capital-Intensive Mega-fabs to Fast-turnaround Mini-fabs. Traditionally VLSI fabrication techniques have relied on large dedicated facilities which required enormous capitalization. Current trends are leaning toward smaller fabrication facilities. Such facilities can be altered on an incremental basis, resulting in reduced capitalization requirements and faster turn-around times with respect to introducing new products.

From Customized, Human-Intensive Software Design/Assembly to Computer-Aided Software Engineering (CASE). The newly-emerging automated design aids provide significant leveraging upon the capabilities of design

personnel. Accuracy, productivity, and cost elements are all enhanced by this approach.

From Computers as Computational Tools to Computers as Knowledge Access Tools (e.g., Hypermedia). Maintaining effective C³I systems will require an increasing ability to manage information. Yet, the increase in available information due to faster and more powerful sensors and computers is exceeding our capability to manage. Techniques are being developed to use the computer as a tool to manage this process of searching for, collating, and presenting information requested by a user, and doing it at speeds many orders of magnitude faster than a human. Such approaches will revolutionize the entire process of information seeking and will likely introduce a cultural evolution in new information managers.

From Instructor-Intensive Training to Self-Paced, "Just-In-Time" Training. The use of computers as information managers affords the opportunity of packaging instructional material geared to specific tasks or problems so that they can be accessed in real-time as needed. Such an approach has the ability to provide pre-packaged instruction and to instruct the user on nearly all possible situations that can be encountered.

From Conventional Explosives to High-Energy Density Munitions (100 x TNT). In addition to the obvious advantage of increased power delivery, this approach could also result in smaller and lighter delivery platforms. Such capability in the hands of terrorists would greatly increase their effectiveness in exporting terror across international boundaries.

From Narrow-band (kb/s) Voice and Data Communications to Wide-band (Gb/s) Voice/Data/Graphics/Video Communications. The increasing use of optics technology is beginning to provide gigabit bandwidths to communication channels for the simultaneous transmission of imagery and graphics with voice and data. This technology provides a much richer information environment for command, control and communications.

The listing of current and potential paradigm shifts in Appendix F are intended to be exemplary of the increasing potential for technological surprise in an era of rapid technological change. Paradigm shifts abound and will accelerate in the future. The Task Force found that potential impacts of technical surprises and/or paradigm shifts on

future conflicts are sufficiently important to warrant special efforts and resources to identify and respond to these possibilities.

The Task Force also found that broad capabilities are needed for performing appropriate "net technical assessments", using traditional Red vs. Blue wargaming comparisons. Simulations and wargames used for these assessments should have additional capabilities for inserting, investigating, and assessing alternative doctrines, tactics, systems, and technologies. Resulting assessments should allow DoD to identify areas where technological surprise or a paradigm shift could be a decisive factor. Such identification is a prerequisite for preparing a defensive strategy against such an occurrence.

3.0 INDUSTRIAL BASE

3.1 INTRODUCTION

The industrial base can be viewed as consisting of

- 1) the DoD funded research, development and production capability of DoD organizations, laboratories and contractors and
- 2) the commercial sector of the US from which DoD buys equipment and services.

In times past, this industrial base has demonstrated it can respond and surge to meet wartime requirements in a manner that is achieved only by world powers. More recently, however, the focus and consistency is less clear or missing.

As DoD plans for the future, the critical dependency on an industrial base remains as important as the past, but there are new factors that must be incorporated. First, the industrial base DoD draws on is now global. The US no longer dominates technology superiority nor cost competitiveness, and therefore, foreign suppliers, dependencies and controls are the new DoD management challenge. The second major factor is the shift of technology advancement from the predominantly DoD funded and controlled programs to non-DoD commercial technology over which DoD has less influence. This dual technology, from the commercial sector, is not only growing beyond the DoD pace of technology, but it often can no longer be obtained from within the US industrial base. DoD must continue a strong investment, but new processes and policies are necessary to manage a far broader technology and industrial base.

While it is clear that a critical dependency on this industrial base is a new national, as well as DoD, challenge, it is also clear that such an industrial base must meet national security objectives, namely:

- Assured access to state-of-the-art technology, engineering, and manufacturing from US as well as foreign suppliers.
- Process improvements to achieve lower cost, higher quality, and shorter product realization cycles for systems, equipments and parts procured for military needs.
- Assured capability for industrial surge to meet rapid response crisis or wartime needs - the nature of which is becoming increasingly unpredictable (but will clearly be required).

These objectives must be underpinned by two fundamental national resolves:

- 1) Achieving a world class commercial industrial sector in the US. This resolve involves more than DoD, and requires Department and Administration priority, as well as Congressional economic legislation to facilitate an industry-led world class competitiveness. The result will be a strong US industry that can support most DoD needs and reduce foreign dependencies in time of crisis.
- 2) Keeping a sustained capability for the US defense industry to engineer and produce critical military-unique capabilities. This resolve stresses not only a robust engineering capability, but balances investments in production processes and prototypes.

Meeting the objectives, resolves and DoD management challenges are important both to building a military force capable of meeting known or unknown threats, but also to developing a cost effective force.

Finally, the resolve to sustain a robust industrial base in support of national security is not in itself sufficient. To realize the desired objectives, it is necessary for a proactive government role to express defense needs, as part of the DoD technology investment strategy, and to manage implementation within the legislative assistance provided by Congress. The section of this report on Critical Industries outlines a new process that carefully selects industry segments that are critical. The most important aspects of this new process is the requirement to be highly selective by applying discipline, criteria, and above all, judgement on a case by case basis. It is believed a broad forum from DoD, DoC, and industry is necessary, with particular attention to case by case recommendations that provide incentives and/or short-term protection.

3.2 LEVERAGING THE COMMERCIAL INDUSTRIAL BASE

The current DoD "culture" is to maintain a defense industrial base separate from the commercial base. We do not believe DoD can afford the inefficiencies and costs of a separate industrial base. DoD needs to significantly increase selective reliance on the commercial industrial base to:

- provide DoD access to broader technology at an earlier availability date -- field leading edge technology,
- drive down manufacturing costs through use of commercial processes, economic volumes, and flexible manufacturing systems,

- reduce the cycle time of technology development through product/ prototype/ system design to field applications,
- increase product quality by using latest manufacturing processes,
- support surge capability through availability of commercial parts and systems manufacturing capability, and
- assist in satisfying critical industry segment requirements.

Historically, DoD has been a major catalyst to the commercial technology base due to its relative size, leading edge technologies and spin-offs to the commercial sector. Additionally, DoD relations with the universities have benefitted both parties with the universities performing research, providing consultations, and educating scientists and engineers. We must strengthen these traditional leveraging roles.

DoD must find and implement ways to leverage the commercial industrial base. Numerous studies in the 1980's (including the Packard Commission and the DSB) have addressed this issue and have provided specific, complementary recommendations. Very little progress has been made in implementing the recommendations. However, we believe that the current budget environment demands action.

We believe there are three areas for synergy within the defense and commercial industrial base -- development, manufacturing, and products/ practices:

- Technology/product development - significant economies can be gained through basic technology planning and coordination. Resulting competitive product development to common standards for dual-use applications will result in lower costs, higher quality and reliability and higher availability
- Manufacturing capability usage - common usage of commercial manufacturing capability will reduce DoD costs for process development, production and support.
- Buying commercial - benefits will accrue through DoD using common products, common specs and standards and common procurement/ cost accounting practices.

Achieving this synergy will require DoD awareness of commercial base "drivers" and commercial requirements for technology, product development and manufacturing processes. It will also require DoD to overcome barriers to using the commercial base.

Several barriers to effective DoD use of the commercial industrial base are described in Figure 3-1.

Figure 3-1

Barriers to Effective Use of Commercial Base
<ul style="list-style-type: none">• Government Cost Accounting System<ul style="list-style-type: none">- Cost Based Pricing - Cost Data Requirements- Disclosure Statements- Audits• Procurement Practices<ul style="list-style-type: none">- Interpretation of CICA- Military Specification and Standards- Technical Data Rights• Regulation of Commercial Use of Government Property• Logistic Support Concerns• Risk Averse Culture of DoD Contracting Functions<ul style="list-style-type: none">- Major disincentives to Use Commercial Base/Products

The government cost accounting system requires that pricing show a direct relation to costs. This requires collection of detailed cost data on components and subcomponents as well as on manufacturing costs. In the commercial world, these costs are proprietary; therefore, there is great reluctance to provide disclosure statements required by the government system. Collecting the cost data and frequent detailed government audits require significant overhead. These factors effectively preclude mixing government and commercial business and the opportunity for DoD to reap benefits from the commercial industrial base.

Government procurement practices inhibit efficiency. Overly conservative application of the Competition in Contracting Act at the technology base level slows the contracting process and adds overhead sometimes equal to the basic cost of the technology work being performed. Higher levels of management have properly interpreted CICA and its applications to systems development and other large procurement programs. However, CICA should not be applied to the technology base.

DoD continues to mandate mil specs and standards in procurements where commercially available products would provide equal or better Service at lower cost. Technical data becomes an issue in joint technology development programs with restrictions on the non-DoD application of this technology.

Many unique DoD laboratories and test facilities could be used effectively by industry to contribute to the national technology data base. Restrictions on their use, however, do not permit effective use of these facilities. Expansion of the 1986 Technology Transfer Act to improve access to laboratories is warranted.

The commercial market has much shorter product cycle times than most DoD weapon systems. DoD is concerned about the ability of the commercial base to provide spare parts for the long-term logistic support of its systems.

The conservative nature of the DoD contracting functions leans against risk-taking with new concepts, ideas and products. "No one ever got fired for specifying mil spec." Also, it is much easier to use an existing mil spec than to adapt to an existing commercial spec. These become major disincentives to DoD using the rapidly evolving commercial base.

Overcoming these barriers will permit synergy with the commercial industrial base. DoD can achieve significant cost avoidance, field technology sooner, gain in system reliability, solve long-term logistic support and increase its capability to meet surge requirements by leveraging the commercial industrial base. The current financial environment in DoD mandates that the barriers to leveraging the burgeoning commercial industrial base be eliminated.

3.3 CRITICAL DEFENSE INDUSTRIES

Continued erosion of defense "critical industries" and whole industry segments is expected to accelerate as funding for defense RDT&E and production declines over the coming years. "Critical Industries" are those considered essential to national security needs. The DoD has no structured approach to deal with this problem, either in terms of identifying "critical industry" segments or in developing aggregate strategies. Indeed, the Department of Defense has been operating on an ad hoc basis as issues surface from various quarters, particularly Congressional actions and inquiries.

Two recent examples of DoD response to "critical industry" issues can be found in the microelectronics and machine tool cases. Both of these industry segments have been seriously eroded by foreign competition. The machine tool case arose from a petition by the National Machine Tool Builders Association to the Department of Justice, subsequently leading to DoD involvement. The microelectronics issue also arose through industry associations and the DoD found itself in a reaction mode, having no cohesive process in place to deal with the issue. In both of these cases, the resultant solution was an industry-led consortium to perform collective R&D for member companies. For machine tools, the National Center for Manufacturing Science was formed and supported in part by a DoD-directed grant from the Air Force Manufacturing Technology Program. In the semiconductor case, SEMATECH was formed and supported in part by a major grant from DARPA.

DoD policies are woefully lacking in terms of nurturing and stimulating domestic critical industries that are critical to national security. Solutions should focus on strategies to leverage defense investments to bolster critical industries, and should be tailored to specific industry segments. More specifically, solutions should focus on defense industry segments that supply materials and components, products, weapon systems and most important, those industry segments that supply design, manufacturing and test equipment. Examples of this latter class of industry segments that have experienced major loss of market share to foreign suppliers include the machine tool industry (discussed above) and more recently the microelectronics process equipment industry.

Ultimate solutions should be focused on assuring the global competitiveness of defense "critical industries" -- not just in terms of DoD or other US Government (USG) financial support. One element of a strategy should include leveraging of planned DoD investments in the Science and Technology Program, the Manufacturing Technology Program and weapon system development and production programs. This approach would ensure that critical industry support is directly tied to DoD needs and production requirements, thereby avoiding a subsidy scenario. There are also currently existing mechanisms that can be utilized to bolster defense "critical industries". Most notable is Title III of the Defense Production Act which provides for government support to critical commodities that are necessary to meet national security needs. Long range strategies must also seek to integrate civil and military industries in order to enhance competitiveness in the defense industry. Efforts must be

directed towards reconciling such areas as different cost and performance considerations, different technical approaches and different types of regulation in order to achieve greater commonality between civilian and military industry. Civilian producers would find the defense business more attractive and would give the DoD a larger potential industrial pool, particularly at the sub-tier level.

It is essential that industry have the lead role in ensuring a competitive industrial base -- this policy has been and should continue to be the cornerstone of defense policy. However, it is essential that DoD develop a cohesive methodology to assess and identify industry segments that are critical to national security needs. The key to such a process is a well defined set of criteria which can adequately assess the current environment and which must be vigorously applied if the process is to be successful. Finally, DoD and other major USG players must strive together towards the common goal.

The methodology for identifying a "critical" industry can be described as follows: An industry or industry segment is considered to be "critical" when all of the following seven criteria are met: Defense Test; Technology/Manufacturing Process Test; Reconstitution/Surge Capability Test; Vulnerability Test; Linkage Test; Alternate Supply Test; and Government Leverage Test. This methodology and criteria were derived from the DSB* study on "Critical Industries".

1. The Defense Test determines the industry/industry segment's relationship to critical defense needs. Industrial products must either go into defense goods or constitute tools or materials in their manufacture.
2. The Technology/Manufacturing Process Test assesses the rate of change of the technology and/or manufacturing process. This test compares the differential between the leading edge and trailing edge of the technology and/or manufacturing process. "Criticality" within this context will be the situation where the leading edge is farthest ahead of the trailing edge. (i.e., a high rate of change)

* Publication expected in the Fall of 1990.

3. The **Reconstitution/Surge Capability Test** assesses the ability of the industry to rapidly increase or reconstitute its production volume to meet mobilization requirements. Are there barriers to the industry's entry/re-entry in order to reconstitute its production line and meet surge requirements?
4. The **Vulnerability Test** will assess the vulnerability of the industry/segment to foreign political intervention (as opposed to market forces), thereby causing a loss of rapid access.
5. The **Linkage Test** indicates the degree of vulnerability of the industry/industry segment to global market forces. The degree of vulnerability will be raised when the industry/industry segment is an essential link in a high volume industrial "food chain".
6. The **Alternate Supply Test** looks at the availability of alternative and substitute products/processes within both the domestic and international market. This test will serve to assess the likelihood of assured access in time of need.
7. The **Government Leverage Test** determines if government policies, laws or investment can have the needed supportive effect on the industry/industry segment. Government leverage is still necessary even if all the other tests have been met to constitute "criticality".

If a US-based, US-owned industry or industry segment meets all seven criteria, it is either not competitive or about to become not competitive on a global scale.

The above criteria are largely qualitative in nature. A quantitative element needs to be introduced** . Although more definition of the quantitative assessment step is needed, Appendix G presents one example of the application of the above seven criteria to the

** See recent quantitative analysis of the "Vulnerability" in a TASC report "Vulnerability of Critical Industries", 1 March 1990 – prepared as part of a draft (not yet released) DARPA report "Defense Dependence on Foreign High Technology - An Assessment of U.S. Vulnerability."

precision optical industry^{***} to assist in interpretation of the aforementioned criteria. Quantitative input to the above criteria set could be accomplished in manner similar to that used by this Task Force in prioritizing Critical Technologies and Core Technologies.

3.4 TECHNOLOGY TRANSFER POLICY

3.4.1 TECHNOLOGY TRANSFER DILEMMA

As is outlined in Figure 3-2, decision-makers in the area of technology transfer policy are currently addressing a dilemma.

**Figure 3-2
Background**

- **CURRENT CONTROL SYSTEM IS NOW OUTDATED**
- **MISSILE, NUCLEAR AND CHEMICAL CAPABILITIES PROLIFERATING**
- **SOVIET TECHNOLOGY ACQUISITION METHODS UNCHANGED**
- **COORDINATING COMMITTEE (COCOM) CONTROLS ARE SHRINKING RADICALLY**
- **TECHNOLOGIES THAT ENCOURAGE A MARKET ECONOMY AND DEMOCRATIZATION IN THE SOVIET UNION REQUIRE SPECIAL ATTENTION**
- **THIRD COUNTRY RESTRICTIONS ARE A PROBLEM FOR US INDUSTRY**
- **FOREIGN INVESTMENT IN THE US IS INCREASING SHARPLY**
- **ASSURED US ACCESS IS NOT CURRENTLY CONSIDERED IN INTERNATIONAL TRANSACTIONS OF TECHNOLOGY**

With the Soviet threat decreased, the globalization of technology, and the increased pressure to export US products and technologies to keep pace with economic competitors (such as the EC), the export control system targeted against the USSR and other communist countries is outdated. It has been effective for the past forty-plus

^{***} Extracted from the Joint Logistics Commanders Precision Optics Study, 19 June 1987.

years, but it needs changing. Other export controls such as munitions, proliferation of dual-use technology useful in nuclear systems, and the missiles control regime need to be examined.

But the security threat has not decreased in certain regional theaters, especially with the possible introduction of weapons of mass destruction such as nuclear, ballistic missiles, and chemical warfare into the Middle East. As the export control lists are reduced, certain enabling technologies and products need to remain under control.

While the Soviet threat has diminished, there is evidence that their need for Western technology in their weapon systems has not diminished. In fact, these illegal activities may increase to meet their modernization requirements.

When the various factors were taken into account, CoCom member countries recently decided to maintain CoCom as a viable organization but radically reduce the export control list to meet the new realities and encourage the modernization of the commercial sector in Eastern Europe. Special attention should be placed on those products and technologies that encourage democratization such as communications.

Third-country restrictions placed on foreign products containing US components and subsystems (military and commercial) have encouraged foreign companies to avoid or "design out" US products.

DoD's assured access to defense critical technologies has been threatened by foreign investment in certain US high technology companies and the movement of those defense technologies overseas. With foreign companies leading in some technologies, there exists no systematic effort for DoD to gain access to these technologies. While assured access is discussed widely in US governmental and industrial circles, there is no systematic effort to make "assured access" a fundamental consideration in foreign investments or technology transfer.

The debate between proponents of allowing the free flow of high technology across national boundaries and those arguing for restrictions has never been sharper. Since WWII, the US has had a fairly successful effort to delay or mitigate the transfer of dual-use technology. The system is characterized by lists made to several levels of indenture that lay out the proscribed technologies. Lists of critical technologies have concentrated on what we don't want others to get. They have not concentrated on what is critical for our economic competitiveness in the world market, nor what could

be of such benefit to our potential adversaries that it would make an impact on our relative force balance.

This reciprocal treatment concept probably also applies to the area of foreign ownership. American companies should be able to acquire capital resources in other countries on an equal footing with foreign ownership in the US. Another consideration is then whether or not today's investors could become tomorrow's opponents. However, a policy that would assure US access to foreign-owned technology would alleviate this concern.

As DoD moves to greater use of commercial products, the opportunity arises to help maintain US economic competitiveness in world markets. Additionally, we expect that desirable technology transfers could occur out of the Soviet Union into world markets. With more open and two direction transfer of technology comes the necessity to place more stringent protection on some small subset that is vital to national security; specifically, on export controls governing the proliferation of dual-use products and technologies useful in nuclear, ballistic missile and chemical warfare applications. In the formation of the subset pertinent to national security it is unlikely that this can be specified in terms of enabling technologies. If this is so then proscription at the part level applies. This then implies an increasing reliance on intelligence to discern military usage of these enabling technologies. Violation of this smaller rule-set should carry larger penalties, particularly penalties aimed at responsible companies or individuals. It should be noted that this level of enforcement implies mandatory participation, a feature that has never been accomplished.

Finally, it is not reasonable to assume that this large organization, which includes several areas in DoD, Commerce, and the State Department, with a historical control mission and marginal enforcement mechanisms, can transform itself into one with an export improvement mission and a strong police function over a small but tightly controlled set of technologies. Such a reformation may require a flat, or stringent guidelines analogous to those of the base-closure commission.

3.4.2 EAST-WEST TECHNOLOGY TRANSFER

As is summarized in Figure 3-3, there is extensive experience in East-West Technology Transfer Control.

Figure 3-3 East-West Technology Transfer Control

BACKGROUND:

- 40+ YEARS AGAINST COMMUNIST COUNTRIES

TECHNOLOGY:

- MEDIUM TO HIGH

PARTICIPANTS:

- 17 COCOM MEMBERS

FINDINGS:

- COCOM STILL NECESSARY
- CHANGING THREAT REQUIRES LIST REDUCTION WITH:
 1. LESS EMPHASIS ON INDIVIDUAL END ITEMS
 2. GREATER EMPHASIS ON COMPLETE SYSTEMS WITH DIRECT MILITARY APPLICATIONS
 3. INSUFFICIENT DIFFERENTIATION FOR EASTERN EUROPE
- RESPONSIBILITY WITHIN DoD DIFFUSE

Since 1949, an informal organization called the Coordinating Committee (CoCom) has relatively successfully impeded communist countries' efforts to acquire (legally and illegally) high technology commercial products and data that could be used in their massive military effort. The CoCom cooperating countries' membership has evolved over the years, to include 17 countries (NATO members, except Iceland, plus Japan and Australia). The export control list developed by the CoCom countries has been long, complicated, and broad reaching. In addition, different implementations by several of the CoCom members has resulted in often confusing regulations for international companies that operate in different markets.

With the toppling of the Berlin wall and subsequent establishment of burgeoning democracies in certain East European countries and democratizing/ free market trends in all Warsaw Pact members, CoCom members decided in early June 1990 to significantly reduce the export control lists. Certain of the reductions were immediate (liberalization of computers, machine tools, and telecommunications) for all the target countries in the Warsaw Pact. Other liberalizing steps are to be taken in early 1991 when CoCom members would have developed a new "core list". The stated goal by the CoCom members is to have a short export control list that contains only those items that have a direct relevance to Soviet military capability.

CoCom remains a viable institution and has shown flexibility by adjusting to the new realities in the Warsaw Pact. It should not be disbanded or significantly modified. While several East European countries have largely "removed" themselves from the military arm of the Warsaw Pact, the long-term stability of the USSR remains unclear.

With a functioning CoCom, appropriate steps can be taken, depending on the direction that the USSR takes.

Within the US government, the processing of export licenses is led by the Department of Commerce (DoC), but DoD plays a dominant role. Policy development for export controls is shared between DoD and DoC. Within DoD, the coordination lead is taken by the Defense Technology Security Agency (DTSA), but recently, JCS has been given a significant role. Also the Services play a significant role, especially in the development of new export controls lists.

Lastly, while the target countries remain the communist countries, licenses are required for exports of controlled products to most free world destinations to prevent diversion to communist countries. These East-West licensing requirements have proved burdensome to US industry and have occasionally conflicted with decisions taken in the context of international cooperative armaments agreements with our allies.

3.4.3 MUNITIONS LICENSES

The sale of defense items which include armaments, support equipment and research and development for such items is governed by ITAR (International Traffic in Arms Regulations).

As is highlighted in Figure 3-4, the regulations are, in principle, intended to foster the interests of the United States by: (1) preventing the export of defense items deemed critical to national security; (2) serving as an instrument of US foreign policy; (3) strengthening the defense by allowing our friends to defend themselves and our allies to be able to contribute to effective mutual defense; and (4) through international sales, supporting the technological base of US defense industry and reducing the cost of such items to the Defense Department. It is also interesting to note that there is no legal or policy basis for considering the impact of the ITAR on the national economy or national technologic competition.

**Figure 3-4
Munitions Tech Transfer Control**

BACKGROUND:

- **CONTROL MILITARY PRODUCTS FOR NATIONAL SECURITY AND FOREIGN POLICY OBJECTIVES**

PARTICIPANTS:

- **UNILATERAL**

FINDINGS:

- **GROWING CONFLICT WITH OTHER CONTROL REGIMES**
- **CONSTRICTS POTENTIALLY GREATER EXPORT**
- **RESTRICTIONS OF RETRANSFERS TO 3RD COUNTRIES AFFECTS EXPORTS**

Unfortunately, in the years since the ITAR was implemented, the associated system of technology transfer controls has not kept pace with the above goals that it was designed to serve. The system has erred on the side of being highly restrictive and cumbersome. It has impaired US industries' ability to: (1) cooperate with our allies on joint programs (usually because of "Military Critical Technology" restrictions); and (2) compete in the global free world market (where our allies do not have similar restrictions). The ITAR has been a poor instrument of US foreign policy with friendly nations and allies, in large part because we are perceived as arrogant, insincere, and unreliable partners for defense cooperative programs.

3.4.4 THIRD COUNTRY MUNITIONS RE-TRANSFER RESTRICTIONS

Procedures and policies on third country munitions re-transfers are principally rooted in security considerations and some past administration's desires to minimize US content in military equipment around the world.

These procedures have had a major negative impact on the US industries' technological base by limiting US sub-contracting opportunities around the world. This has been the case because the policy implemented through licensing procedures does not provide for approval in advance for a nation's ability to sell its equipment to free world

countries if there is any US content but requires a case-by-case approval in the future before such a sale can be made. Our allies and friends around the world have, therefore, avoided any US content in their defense equipment so as to not be restricted in their ability to market such equipment internationally, without a possible US veto, or at best, a lengthy US approval process.

As this panel has pointed out, commercially available technology is becoming more and more a foundation for our defense equipment. Therefore, an approach similar to that now applicable for dual-use third country re-transfers should be applied to munitions case. This approach is based on automatic approvals below a certain percent of US content for any given equipment, as long as other control criteria are not violated. The present procedures dealing with commercial technology place no US restrictions on equipment whose US content is below 25%. This percentage seems arbitrary, and the task force sees no reason for additional restrictions (beyond the above-noted security restrictions) where US content is below 50%.

3.4.5 PROLIFERATION

Concern over proliferation has existed since it became apparent that more than just a few select nations wanted the capability to make a nuclear weapon. At first, the nuclear proliferation regime was, by its very nature, a program with a select group of members. While many people know of its existence, few actually were involved. As more countries have become technologically sophisticated, and in some cases desirous of possessing a nuclear weapon, the technologies of concern as well as countries have expanded; however, this expansion still draws on the basic control process established early on.

In recent years, new proliferation concerns, both missile and chemical, have surfaced (see Figure 3-6). The Missile Technology Control Regime (MTCR) officially started in the Spring of 1987 and stemmed from concerns that more small, less-developed, third-world countries were demonstrating capabilities to acquire, assemble, and in some cases, launch missiles capable of traveling in excess of 1000 km with warheads weighing more than 500 kg. The MTCR currently consists of seven countries that, under written agreement, have stated they would limit the flow of certain items and technology to other countries who have demonstrated either the desire or intention to become missile capable. In most cases, the items or technology of concern are not first level, but rather second or even third generation.

The third area of proliferation concern, and one that has received much attention recently, is in the area of chemical munitions that have been made and used by an increasing number of less-developed, third-world country nations. The use of these weapons by these countries has fostered international concern and the call for action. The precursor chemicals that are used to make these weapons have been easily obtained while the technology needed for combining them into chemical weapons is rudimentary.

The potential for a significant shift in the balance of power resulting from a nation's acquiring the capability to fabricate a nuclear weapon has increased. Today an increasingly large list of countries are considered to be capable of achieving nuclear capability in certain time frames. In the area of missile and chemical proliferation, the potential for destabilizing a region by introduction of long, stand-off or cheap weapons of "mass destruction" has been increased.

**Figure 3-6
Proliferation Tech Transfer Control**

BACKGROUND			
	NUCLEAR	MISSILE	CHEMICAL/BIO
EXPERIENCE:	LONG	NEW	NEW
TECHNOLOGY:	DUAL-USE (HIGH TECH)	DUAL-USE (AEROSPACE RELATED TECH)	PRECURSOR CHEM (LOW TECH)
TARGETS:	12 COUNTRIES	15 COUNTRIES	20 PLUS
PARTICIPANTS:	7 COUNTRIES	7+ COUNTRIES	20 COUNTRIES
IMPLEMENTATION:	SOME	POOR	POOR
FINDING			
<ul style="list-style-type: none"> • UNCOORDINATED EFFORT IN USG • MULTILATERAL COORDINATION INSUFFICIENT (USSR NOT INVOLVED) • EXPORT CONTROL LISTS TOO BROAD 			

Many of the countries that are of concern in all the proliferation areas are politically and militarily unreliable and clearly add to the uncertainty where proliferation is concerned.

The control regimes for each of these three areas, while generally under the aegis of the State Department, have been established in three different time frames and involve different offices within the DoD. Many of the nations that have agreed to the MTCR and the chemical proliferation controls do not coordinate or even standardize their control lists or mechanisms. Often foreign control lists of equipment and technology are too narrow while the US list is much broader in its coverage.

3.4.6 ASSURED ACCESS

DoD's assured access to critical technologies is threatened by two phenomena, the purchase by foreign countries of US high technology firms, and the movement abroad of critical technologies by US companies. Figure 3-7 highlights important aspects of this problem.

**Figure 3-7
DoD Losing Access to Core/Critical Technologies**

BACKGROUND:

- FOREIGN DIRECT INVESTMENT INCREASING SHARPLY IN DEFENSE-RELATED, HIGH TECHNOLOGY INDUSTRIES
- CFIUS REVIEW IS INTENDED TO PROTECT US INTERESTS
- CERTAIN CRITICAL TECHNOLOGY COMPANIES TRANSFER TECHNOLOGY OVERSEAS
- INCREASED CONCERN IN CONGRESS AND THE US PUBLIC OVER THE LACK OF ACTION BY THE USG AND DoD TO ASSURE ACCESS TO CRITICAL TECHNOLOGIES

FINDINGS:

- CFIUS* REVIEW INADEQUATE TO ASSURE ACCESS
 - DATA BASE INADEQUATE
 - MANY DoD CORE AND CRITICAL TECHNOLOGIES ARE NOT CONSIDERED
- UNCOORDINATED GOVERNMENT INTERVENTION IN DoD CORE/ CRITICAL TECHNOLOGIES/INDUSTRIES MOVE OVERSEAS

* COMMITTEE FOR FOREIGN INVESTMENT IN THE US

With respect to foreign direct investment in the US -- which involves 400-500 cases annually and is steadily growing in several key industries, notably electronics -- the USG is empowered to evaluate each case to assure itself that the foreign firm is not purchasing a critical technology with the intention of removing it abroad.

Unfortunately, the inter-agency group responsible for the evaluation, the Committee for Foreign Investment in the US (CFIUS), is weakened by the scarcity of useful data and absence of guidelines on "critical industries." The lack of data is largely the result of poor coordination among US agencies responsible for collecting it, particularly the Bureau of Economic Affairs and the Census Bureau, both part of Commerce. DoD should lend its influence to bring greater order to the collection and dissemination of information regarding foreign direct investment.

More important, DoD should be playing a much more active and effective role in assuring that CFIUS research is thorough and meaningful. At present, CFIUS largely restricts itself to a snapshot of the investor and the technology. There is little or no effort made to examine the past history of the company or country, or the future likelihood that its investment might result in the loss of assured access by the US. There is also little or no effort made to evaluate the impact of the technology on upstream processes or downstream products, or on its potential future significance in terms of military security.

Granted that the loss of assured access by DoD to a critical technology through foreign ownership is not likely; nevertheless, DoD should play a responsible role in the process provided by law to assure that it does not happen at all. (For a lengthier analysis of this issue, see the DMB Task Force Report on Foreign Ownership and Control)* .

The other half of the threat to assured access comes from the occasional practice by US firms of moving critical technology abroad, usually as the result of joint ventures with foreign firms or through sales. The US company is apt to be a medium or small size firm, in need of capital which it is unable to find in the US at reasonable cost or with reasonable conditions. Regardless of the cause, the DoD could be a loser if the

* Due for release in the fall of 1990.

technology meets the criteria for criticality and the US firm does not receive reciprocal benefits in the US.

Since each case represents a different set of circumstances, it is difficult to fix on a specific set of recommendations, beyond the need for DoD to play a much more active role in assuring a maximum USG effort to hold on to endangered technology. Such an effort could include utilizing incentives to the US company to keep its technology or sell it to another US firm, or for the foreign purchaser to retain the technology here; or, if it is removed, to take appropriate steps to assure its return through licensing, contracting, or other means.

3.4.7 DOD ORGANIZATION OF INTERNATIONAL ACTIVITIES

Dealing with the interdependent, and sometimes conflicting, matters of protecting critical technology, strengthening the defense technology base of US industry, removing obstacles to the export of dual-use products and technology, providing security assistance to our friends and allies, and engaging in cooperative defense research, development and production programs with our allies is difficult. Within DoD, dealing with these matters is more difficult by the current organizational structure.

Apart from policy-making considerations, there are currently three organizational entities within OSD with significant responsibilities for implementing policy in the international arena: the Defense Security Assistance Agency (DSAA), dealing with foreign military sales; the Defense Technology Security Administration (DTSA), dealing with munitions licenses, DoS/DoC commodity jurisdiction cases, and strategic West-East trade, and the Deputy Under Secretary of Defense for International Programs (DUSD(IP)), dealing with international cooperative programs in research, development and production. There are about 300 people in these organizations. DSAA and DTSA report indirectly to the USD(P) and DUSD(IP) reports to USD(A). The Director of Defense Research and Engineering (DDR&E), also reporting to USD(A), is responsible for providing technical advice to all of these organizations.

The existence of three implementing organizations creates many opportunities for disorder, including: overlapping and duplicative functions; inadequate attention to emerging needs (such as evaluations of proposed foreign investments and acquisitions, and provision of assured access); inconsistent corporate behavior (such as approving transfer of technology as part of an FMS arrangement and denying the

transfer of the same technology as part of a direct sale); an array of confusing focal points for other Departments and Agencies, foreign governments, and US and foreign industry; and lengthy delays in execution of acquisition activities involving foreign governments and industry. Currently, the only senior OSD official with the responsibility for the entirety of these activities is the Secretary of Defense, and it is not reasonable to expect the Secretary to devote the day-to-day attention required.

These organizational difficulties are not new. Indeed, they have been addressed by three previous studies: the January 14, 1977 Report of the Security Assistance Task Force (known as the Wiley report); the June, 1983 Defense Science Board Task Force Report on Industry to Industry International Armaments Cooperation, Phase I - NATO Europe (the Currie report); and the 1989 Defense Science Board Task Force on the Pacific Rim. Yet the difficulties remain.

4.0 FINDINGS AND RECOMMENDATIONS

4.1 INVESTMENT STRATEGY

Findings on Investment Strategy

- **A good foundation exists for building a coherent technology investment strategy and an integrated management process**
 - **The US has world class capability in most technologies (and most weapons systems)**
 - **There is a large cadre of dedicated scientists and engineers**
 - **Excellent examples exist of processes which work**
 - **The US has an excellent industrial base in most technical areas**

BUT...

- **Unified "strategies" and guidance are just now being initiated**
- **There are missing links between scenarios, military capabilities, technology goals, and investments**
- **There is a lack of accountability, measurement, and reward at all levels**
- **The management system provides poor visibility of both input (actual resource allocations) and output (results)**
- **DoD does not invest enough in process and manufacturing technologies**
- **"Critical Defense Industry" and "Leveraging Commercial Base" are not addressed well**
- **The importance and unique characteristics of the S&T program are not reflected in OSD management of the S&T program**

Developing and executing an effective technology investment strategy is obviously not an undertaking which can be completely defined by this Task Force. Within this report we have indicated some important elements which must be included, and undoubtedly have omitted others. We believe, however, that implementation of the following recommendations will produce the kind of technology investment strategy needed by DoD.

First, we believe the personal involvement of the USD(A) is essential in leading DoD efforts to improve technology strategy process, resource

management and evaluation. Only in this way will the necessary degree of "corporate" leadership and commitment be infused throughout DoD, and only in this way will the necessary degree of importance and priority be attached to the management of the S&T program.

RECOMMENDATION: USD(A) establish a permanent executive position, the equivalent of a "corporate CEO" position, reporting directly to USD(A) and solely responsible for the formulation and execution of the DoD Science and Technology program. It should be noted that this position differs from the position of DDR&E in that it has both TOA authority and execution responsibility. It is envisioned that the DDR&E would continue to coordinate activities other than the S&T base.

Implementation of this recommendation would:

- Place exclusive responsibility and authority for the DoD S&T program firmly in the hands of one person. We believe this to be absolutely vital. Apart from any other management reforms related to the total DoD RDT&E program which may be desirable, which we did not address, we believe that there must be one person with exclusive responsibility for S&T. There is currently no such person; while the current position of DDR&E nominally has responsibility for all S&T except that of SDIO, the position has responsibility for many other non-S&T matters as well, and does not have S&T TOA authority. We do not believe that any position which has significant non-S&T responsibilities will provide for adequate OSD management of the DoD S&T program. Although we did not conduct a detailed management organization review to determine the best organizational location of such a position, it obviously must be consistent with the responsibility and authority assigned.
- Provide centralization of the following functions as the responsibilities of the "CEO":
 - Development of policy for all S&T matters
 - Development and oversight of the execution of a single, unified DoD technology investment strategy, including goals, objectives, priorities, and resource allocations
 - Establishment of the S&T TOA for each DoD Component

- Approval/disapproval of the S&T plans and programs of the DoD Components
- Provide decentralization of the following functions as the responsibilities of the DoD Components:
 - Development of detailed S&T plans and programs of the DoD Components
 - Execution of S&T programs of the DoD Components
 - Control of S&T personnel and facilities of the DoD Components

We would also expect the "CEO" to champion specific initiatives, such as:

- Selective technology demonstrations to lower risk, evaluate military worth and preserve critical design teams. 6.3A platform emphasis should be reduced accordingly
- Selective joint Service projects where contributions can be synergistic
- Implementation of evolutionary system improvements by relevant technology insertion
- Innovative high risk/high payoff technology development as an important segment of the total program
- Development of process and manufacturing technologies, both hard (process equipment) and soft (factory C³)
- An IR&D level that is no less than the current level, with proposed increases to accommodate manufacturing technology development
- Placement and continued development of quality personnel at all levels

To Support this recommendation, the Task Force also recommended that:

- Heads of DoD Components establish Service and Agency program executive officers (PEO's) responsible jointly to the CEO and the Service Acquisition Executive for technology investment strategy execution.
- Chairman, JCS establish a JCS organization focused on integrating tactics, doctrine, and technology. Along with this, develop necessary policies and procedures to support a scenario-based technology planning approach.
- DepSecDef increase the current level of technology base (6.1, 6.2, 6.3A) funding for future technological leadership, but tied to major reforms.

If this recommendation is implemented, the Task Force believes that many of the weaknesses identified above can be overcome.

Unified DoD-wide "strategies" and guidance can be developed providing stability and focus to the S&T program. The Technology Investment Strategy developed by the CEO must be an integrated strategy for all 6.1, 6.2, and 6.3A resources. This strategy should consider the individual and collective requirements and capabilities of the Military Services, SDIO, and Defense Agencies. The strategy must also identify the critical technologies that provide potential for a significant warfighting advantage and the core technologies that are required to maintain, strengthen, or establish a needed competence.

Missing links between scenarios, military capabilities, technology goals, and investments can be developed. A disciplined methodology should be used to provide the needed linkage between scenarios, desired military capabilities, technology goals, and technology investments. The importance of providing for the development of innovative, high risk/high payoff technology cannot be overemphasized.

A system of accountability, measurement, and reward can be developed at all levels. The CEO can devote the time necessary to conduct semi-annual reviews of status and progress against the strategic plan, modify the strategy and implementation plans as required, and report findings and key issues.

Greater visibility of both the input and output of the S&T-program can be achieved at the highest levels of DoD. The CEO can insure that the S&T program structure facilitates visibility on both the program input (resource allocation) and its output (performance measurement and evaluation). The CEO can also insure that the management processes focus on both input and output.

Greater investment emphasis can be placed on specific S&T initiatives such as the need for more investment in process technologies. With responsibility solely for the S&T program, the CEO can devote sufficient time to championing key S&T initiatives such as the need for more investment by DoD in process and manufacturing technologies.

"Critical Defense Industry" and "Leveraging Commercial Base" issues can be addressed on a DoD-wide basis. The CEO can establish the necessary structure to provide DoD with approaches toward addressing these two important issues.

RECOMMENDATION: DoD Component Heads establish Service and Agency program executive officers (PEO's) responsible for technology strategy investment execution. These executives would report to the Service acquisition executives, or to the agency director, and would have responsibility, authority and accountability to manage the science and technology programs in their respective organizations in accordance with the strategy established by the CEO. These executives would report status and progress to the OSD CEO, and would elevate issues to that level for resolution. Implementation of this recommendation will eliminate unnecessary financial and programmatic interdiction by peripheral organizational interests.

RECOMMENDATION: Chairman, JCS establish a JCS organization focused on integrating tactics, doctrine, and technology. Along with this, develop necessary policies and procedures to support a scenario-based technology planning approach. Along with centralizing S&T management through the CEO and development of a single, unified investment strategy comes the need to integrate tactics, doctrine and technology. An organization within JCS is needed to support the CEO to focus on the integration of doctrine, tactics, and technology, and to provide proper support for a scenario-based technology planning approach. This organization should develop the policies and procedures to support a scenario-based technology planning approach.

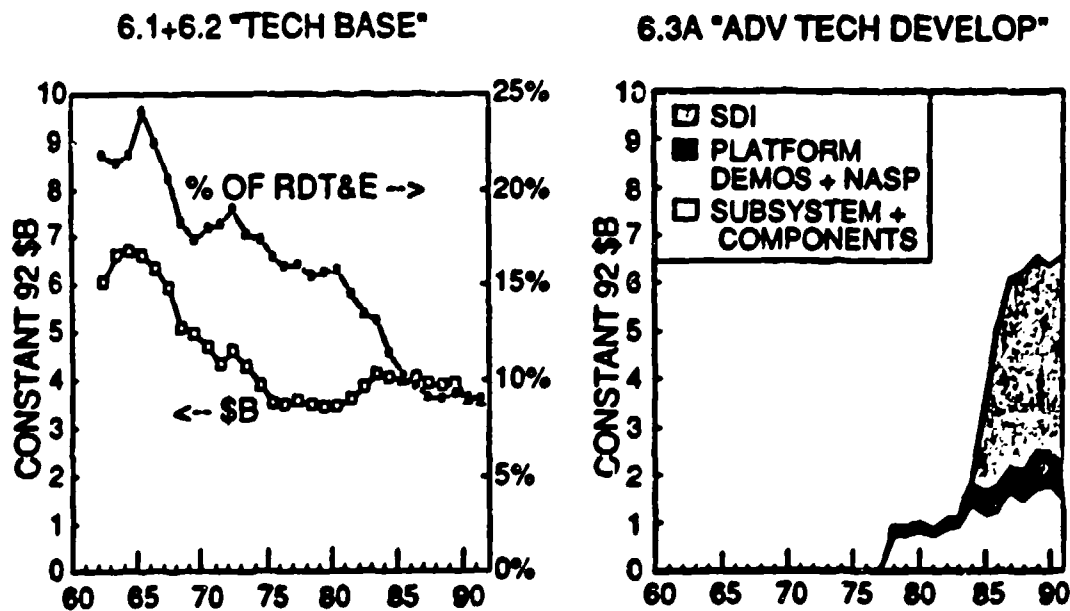
RECOMMENDATION: DepSecDef increase the current level of technology base (6.1, 6.2, 6.3A) funding for future technological leadership, but tied to major reforms. As shown in Figure 4-1, the level of 6.1 and 6.2 funding has been decreasing real terms over the last 3 decades. When major programs (SDI, platform prototypes such as NASP) are removed from the 6.3A funding levels, it is obvious that the 6.3A resources used for component and subsystem technology demonstrations increased only slightly. To effectively build and maintain an adequate technology base in the future, more funding is needed. However, we do not recommend such an increase unless it is coupled with the

Implementation of the major reforms which we have recommended. Without these reforms, we do not believe an additional investment will produce comparable gains in output. It is felt that with an integrated, unified technology investment strategy and an effective management process to implement that strategy, this level of funding will yield much improved output beyond that evidenced historically. This improved return on investment will, to a significant extent, compensate for the increasing cost per man year for professional engineers and scientists (about a 75% escalation over the past ten years). However, maintenance of this level of funding must be tied to major reforms in the planning, management, visibility and execution of the technology program. These major reforms include not only the implementation of the preceding recommendations, but also:

- A definition of the roles, responsibilities, and authorities of all offices/positions which are operative in the technology program (in formulation, planning, execution, and/or resource control).
- A management information system which provides ready visibility of resources allocated to, and progress measures in, aggregate technology areas as well as critical and core technologies.

Figure 4-1

Historical Budget Trends



RECOMMENDATION: USD(A) foster integration with the industrial/commercial/ university base. Proper knowledge of, and utilization of, the technology bases in industry and universities can greatly leverage the DoD technology base investment and significantly improve the return on investment. Utilization of this base can particularly provide leverage in manufacturing process technologies, reduce system cost, and shorten the time from development to fielded system. Specific recommendations for leveraging the industrial base are outlined in Section 4.2 of this report.

4.2 INDUSTRIAL BASE

4.2.1 LEVERAGING THE COMMERCIAL INDUSTRIAL BASE

Findings on Leveraging Commercial Industrial Base

- The current DoD "culture" is to maintain a separate defense industrial base
- The decreasing defense budget requires selective reliance on the commercial industrial base:
 - Technology
 - Cycle time
 - Cost
 - Responsiveness
- DoD must continue to be a major catalyst for the commercial technology base and the university S&T community
- Numerous studies (Packard commission, DSB, DMB, ---) have provided specific, complementary recommendations
 - VERY LITTLE PROGRESS HAS BEEN MADE IN IMPLEMENTATION

RECOMMENDATION: USD(A) should fully implement recommendations of the 1986 and 1989 DSB Summer Study on the use of commercial components and practices and DMB concept of "integrated" commercial/DoD industrial base. Remove the barriers and measure implementation effectiveness. The Task Force had no new recommendations for harmonizing the defense and commercial industrial bases. Rather, we reaffirm the recommendations made by previous DSB and DMB studies on the use of commercial components and practices, and the concept of an integrated commercial/defense

Industrial base. Specific actions to implement this recommendation have been detailed in previous reports and include:

- directing "proper" interpretation of CICA to minimize the contracting process inefficiencies in the tech base program.
- eliminating the burden of the mil standards/ mil specs. increasing the selective use of commercial processes and products in military systems,
- motivating the use of the commercial base through specific changes to acquisition and program management guidelines,
- directing pilot demonstration programs in each Service to demonstrate the benefits of increased reliance on the commercial industrial base,
- mandating changes in the defense cost accounting system to permit mixing commercial and defense business.

A measurement and reporting mechanism should be implemented to gauge progress in accomplishing these actions.

4.2.2 CRITICAL DEFENSE INDUSTRIES

Findings on Assured Access to Critical Components and Technology

- **CENTRAL ISSUE:**
 - Potential demise of capabilities in defense "critical industries"/"critical industry segments"
- **CURRENT STATUS:**
 - "Critical industries" remain undefined and unidentified by DoD
 - There is no DoD/US action plan
 - Some critical industry segments have already moved off-shore -- jeopardizing assured access

RECOMMENDATION: USD(A) should implement the recommendations of the 1990 DMB/DSB Task Force on defense critical industries. The principle recommendations are to:

- Identify critical industries using the 7-point DMB/DSB criteria
- Establish organizational responsibility
- develop tools to permit iterative policy analysis
- develop (with industry) sector-specific actions
- make more "creative" use of the title III of the DPA
- nurture harmonization of the defense/ commercial industrial base

It is essential that the term "Critical Defense Industry" be reserved for only those segments that fully meet all of the criteria. Efforts should be undertaken with other USG agencies with the goal of combining initiatives targeted to specific industry segments. In the short term, USD(A) should establish the necessary infrastructure to measure and track the effectiveness of the critical industries identification process. In the long term, USD(A) should take the lead in establishing a national level infrastructure to ensure critical industry viability.

4.2.3 TECHNOLOGY TRANSFER POLICY

Findings on Technology Transfer Policy

- The current control system is now outdated.
- Missile, nuclear and chemical capabilities are proliferating.
- Soviet technology acquisition methods remain unchanged.
- Technologies that encourage a market economy and democratization in the Soviet Union are not receiving any special attention.
- Third country restrictions remain a problem for US industry.
- Foreign investment in the US is increasing sharply.
- Assured US access is not currently considered by DoD or the US Government in international transactions of technology.

RECOMMENDATION: The Task Force strongly urges DoD to reduce all export control lists. Emphasis should be reduced on end products (such as

computers and semiconductors). End products are indirect contributors to military strength or the proliferation of ballistic missiles and nuclear weapons. Emphasis should be placed on certain enabling technologies, manufacturing equipment and complete integrated systems that have direct military and/or proliferation application. Proper application of this emphasis should result in a very small list of unclassified military or dual-use technologies and products that need to be controlled unilaterally by the U.S. for national security reasons. Subject to restrictions on such items, we more specifically recommend that DoD:

- Decontrol dual-use exports to those East European countries that agree to satisfactory safeguards for Western technology and products and reduce controls to the Soviet Union and others except for a very small "core list" of technologies that would cause a shift in strategic balance (de-emphasize end products).
- Remove licensing requirements for exports of unclassified military products and technologies destined to NATO countries and other selected allies. However, a letter of assurance should be required from the foreign importer that the item would not be used contrary to US export control laws.
- For the much-reduced list of items and technology, especially those that could contribute to the proliferation of missile, nuclear, and chemical capability, demand strict compliance by governments and industry. Penalties should be of the "you bet your company" nature.
- Remove third-country, re-transfer restrictions from all products that contain less than 50% unclassified US components. The Task Force intends, however, that the few remaining, over-riding security restrictions discussed above would remain in force.
- Foreign investment in defense critical technology companies should be reviewed by DoD through the Council on Foreign Investment in the United States (CFIUS) process to insure that there remains an assured access to these technologies.

RECOMMENDATION: SECDEF consolidate and streamline the DoD organizations for implementing all aspects of international defense trade, collaboration on acquisition programs, and technology transfer policy. We further recommend that the consolidation include, first and foremost, the assignment of sole responsibility for these implementation activities to an Assistant Secretary or Deputy Under Secretary level position reporting to the USD(A). These activities include matters concerning defense industrial cooperation, government-to-government agreements, evaluation of foreign investment and critical industries, foreign military sales, and technology export control. This is the fourth time in three separate administrations that the DSB has made such a recommendation. The prior studies have all recommended that this implementation responsibility be assigned to a position reporting to the USD(A), and we agree. The role of USD(P), within DoD, is clearly to establish policy regarding relationships with other countries. USD(A) should be given the authority to execute. This involves all of the management and technical resources needed to streamline the decision/action process and to operate efficiently. These resources include DSAA, DTSA, and ODUSD (International Programs).

4.3 SUMMARY

The funding trends for Science and Technology have not been favorable (see Figure 4-1). With respect to the technology base -- that is, category 6.1 and 6.2 funding -- there has been a significant reduction in buying power over the last thirty years. More importantly, the funding for the technology has not kept up with total RDT&E funding. It has declined from a peak of almost 25% of the total RDT&E funding in 1965 to less than 10% today. These two graphs, taken together, indicate that DoD can afford to spend more to achieve technological superiority.

In the changing environment, DoD must:

- Increase Science and Technology Investment coupled to the implementation of a true technology investment strategy.
- Explicitly address the viability of its industrial base and draw far more heavily on the commercial sector.

APPENDIX A

Terms of Reference for Defense Science Board 1990 Summer Study on Technology and Technology Transfer Policy

The Technology and Technology Transfer Policy Task Force shall examine the full range of technologies both here and abroad and identify those with high potential to provide "leap frog" capabilities to US forces for the next twenty years. Considerations would also take into account access to technology (foreign availability/foreign dependency) and transfer control. Technological, industrial, and trade dimensions will be included. The Task Force will draw on recent Service studies and other appropriate technological assessments. At least three key questions will be answered by this Task Force. What is necessary for the US to be in a world competitive technological position? What role should DoD play in achieving, not only a world competitive posture, but also a world competitive force capability? What should be the DoD policy on technology transfer to specific nations?

The Task Force should ensure consideration of the following questions:

1. How do we identify, assess the payoff, and prioritize key technologies?
2. What criteria, eg. new/changed missions, threat scenarios, economic realities, etc. will/should drive future defense RDT&E investment strategy?
3. What are the technologies (product and process) that promise "order of magnitude" impact on functionality, cost, schedule and/or quality of future military capability?
4. What specific RDT&E investment strategy should the DoD adopt in the future?
5. What are the longer-term technology objectives and paths toward those objectives?
6. How does the current downward trend in defense resources impact the R&D program? What should be done?
7. Can/should the DoD attempt to maintain its own industrial base?
8. How can the DoD make full use of the commercial industrial base and how can the barriers to integration be removed?
9. Can/should "industrial responsiveness" (i.e., a rapid increase in production in response to a military need) be a significant element in our future national security posture?
10. What should be the desired "vision" of the structure of the defense industrial base for the future and what are the appropriate steps for its realization?

11. In view of the changing economic and military environments, how should we revise our technology transfer policies?
12. What is the meaning/measure of "foreign dependency/vulnerability" and what should be our policy?
13. What additional intelligence data are required to assist in future technology strategy development and how should the dissemination of "economic intelligence" data be achieved? Further, are we adequately exploiting open literature?
14. The DoD technology base is the responsibility of many organizations; are changes required in management and organization and, if so, what are they?

The DDR&E for Research and Advanced Technology will sponsor this Task Force. Dr. George H. Heilmeier and Dr. Jacques Gansler will serve as Co-Chairmen. Dr. Donald Dix, USD(A)/R&AT, will serve as Executive Secretary, and Lieutenant Colonel David L. Beadner will be the DSB Secretariat Representative. It is not anticipated that your inquiry will need to go into any "particular matters" within the meaning of section 208 of Title 18, US Code.

APPENDIX B

Participants

Chairmen

Dr. George H. Hellmeier, Senior Vice President and Chief Technical Officer, Texas Instruments, Inc.
Dr. Jacques S. Gansler, Senior Vice President and Director, TASC

Executive Secretary

Dr. Donald Dix, Acting Director, Engineering Technology, ODDR/E (RAT)

DSB Representative

Lt. Col David L. Beadner, Defense Science Board Office, OUSD(A)

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Mr. David S. Tarhell, Director, International Economic and Energy Affairs, OUSD(P)
Mr. John T. Tyler, Director for Plans, DSAA
Mr. David Vaughn, Director of Technology, Marine Corps Research, Development, and Acquisition Command

Support

Dr. Nancy J. Chesser, Mr. Bradford Smith, and Mr. David Thomas

APPENDIX C

Current Status of DoD Technology Base Planning Efforts

C.1. The DoD Science and Technology Investment Strategy

This document, the latest draft of which is June, 1990, focuses on:

- A strategic planning process involving OSD, the three Military Departments, the Defense Agencies (DARPA, DNA, and SDIO) and OSD (BTI).
- The science and technology mission statement.
- Twelve strategic goals for the S&T program, stated in terms of broad future capabilities desired in three areas: deterrence, military superiority, and affordability.
- For the Military Departments, operational needs in terms of next-generation systems and upgrades, and future systems in 14 all-encompassing functional areas
- For the Military Departments, specific technology objectives in support of these operational needs in 17 all-encompassing technology areas, and the S&T investment in these technology areas in FY 1990 and 1991.
- For the Defense Agencies, specific technology objectives in their special focus programs, the related investment, and the relationship of the technology objectives to the strategic goals.

This strategy document represents an excellent first step in developing a comprehensive defense technology strategy. When fully developed, we believe that it can: make explicit all elements of the strategy; provide quantifiable strategic goals in terms of desired future capabilities which would accommodate the spectrum of likely scenarios; establish technical milestones to achieve these goals; provide a rational basis for the identification and care of critical technologies; and significantly improving the focus and resource allocations of the S&T investment. However, much remains to be done (most of which is recognized by DoD); a fully developed strategy must:

- Address all five constituents of the science and technology mission statement; the 1 June 1990 version addresses only the first.
- Establish a clear linkage among the spectrum of likely scenarios, the capability goals, and the related functional area operational needs and thrusts; the current version does not address likely scenarios nor is the remaining linkage clear.
- Provide an explicit rationale for both a logical identification of critical technologies and the allocation of resources among the various technology areas; the current version provides no such rationale.

- Have associated with it an effective process by which it is developed, updated, and implemented; currently, there appears to be no enduring process in place.

C.2. The DoD Critical Technologies Plan (DCTP)

In response to congressional mandate, the Department of Defense has submitted a Critical Technologies Plan to the Congress in each of the last two years. The most recent version contains:

- The criteria used in the selection of the technologies
- A list of twenty critical technologies
- A relative prioritization of these technologies into three groups
- Summary description of the goals, payoffs, milestones, and funding for each technology
- Related current and needed manufacturing capability
- Related research and technology efforts in the U.S.
- An internal assessment of relative U.S. capability and potential areas of contribution from allies.

This is also a notable document, particularly with regard to the last four items in the above list. However, in our opinion, several substantial improvements will be necessary if the concept of critical technologies is to be a viable management tool:

- The critical technologies must be sharply defined and limited in scope; currently, many of these technologies are diffusely defined (and difficult to assess)
- An explicit methodology is needed if the list is to have widespread credibility and support; the methodology appears to one of a totally judgmental consensus by some group of (unnamed) experts
- As we noted earlier, the critical technologies must be an integral part of an overall defense technology strategy, currently, there seems no such integration
- Implementation of the development of critical technologies is of course an absolute necessity; it is not apparent to us that either of the Defense Critical Technology Plans has had any impact on the actual development of these technologies.

C.3. The Defense Technology Strategy and Action Plan (DTSAP)

The report reviewed by the Task Force is Volume 1 of a two volume document dated July 1990. The DTSAP is split into two portions: the Technology Strategy and a series of Action Plans. Overall, the DTSAP contains:

- A statement of purpose for the DoD RDT&E program
- A description of the national security environment and military strategy
- Six objectives, or criteria for selection of technology efforts, stated in terms of broad future capabilities desired
- General descriptions of future capabilities required in five military mission areas and six "cross-cutting" areas
- Illustrative linkages between national security objectives, systems capabilities, and high-payoff technologies
- Action plan charts which show possible technology transition to specific existing systems, potential system upgrades, and new systems
- A compendium of technology objectives, extracted from the DoD S&T Investment Strategy document, listed by mission area and technology area
- A brief description of an overall RDT&E management philosophy

The DTSAP was prepared within the Office of the Director, Defense Research and Engineering and uses some portions of the DoD S&T Investment Strategy. The document reviewed by the Task Force was presented as a first draft requiring further work to complete. While the illustrative linkages between national security objectives, systems, and technologies is a positive step, much remains to be done to produce an effective strategy. Further, the unclear relationship between the DTSAP and the S&T Investment Strategy (e.g., five military mission areas and six "cross-cutting" areas in one document and 14 functional areas in the other, six broad objectives in one document and twelve in the other) is a cause of great concern. Clearly, there needs to be an enduring process by which a single, unified strategy can be developed, updated, and implemented.

APPENDIX D

Identification of Critical Technologies

D.1 Overview of Methodology

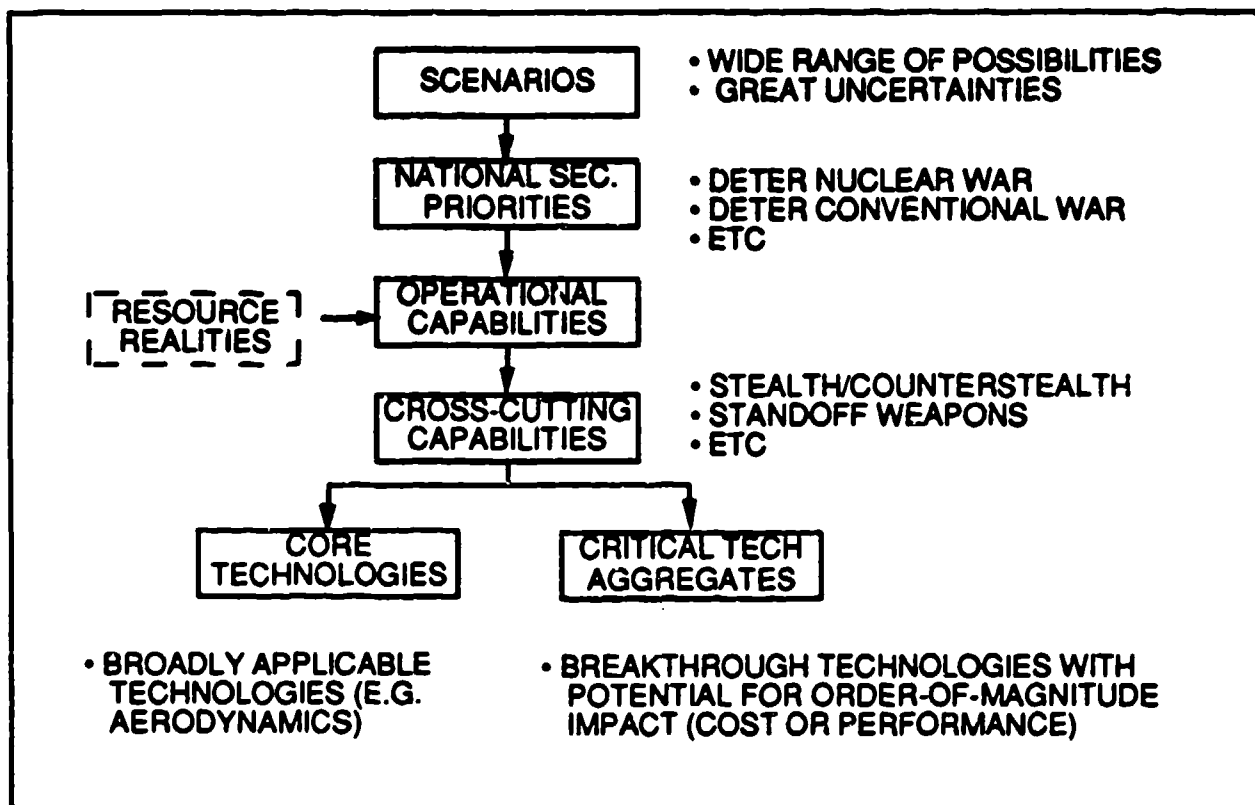
The Task Force considered several possible methodologies and determined that a scenario-based methodology is best for selecting those technologies that are critical to the future national security objectives of the United States (see Figure D-1). This methodology consists of the following sequential steps:

- A. Establish a mutable set of scenarios which represent a wide range of potential futures, but which also recognize great uncertainties;
- B. Derive from those scenarios a set of national security priorities, e.g. deter nuclear war, deter conventional war, etc. (As a practical matter the panel adopted the President's "National Security Strategy of the United States" as the conceptual backdrop for subsequent steps in the process.);
- C. Compare national security priorities with current operational capabilities to identify relative "overshoots" and "undershoots";
- D. Match operational capabilities against resource realities and identify those cross-cutting capabilities essential to more than one set of operational capabilities that have especially high leverage (stealth, counter stealth, standoff weapons, etc.);
- E. Devolve the cross-cutting capabilities into technology aggregates. Then, sort out both critical technology aggregates that portend order-of-magnitude impact (in either cost or performance) and essential core technologies which have broad applicability and are essential to operations of the forces.

The text to follow represents the Task Force analysis using this methodology.

Figure D-1

Scenario-Derived Critical Technologies



D.2 Scenarios

The Task Force identified the following overarching security scenarios:

USSR:

- A. Return of the Cold war with the USSR: The threat of internal political disorder might force the USSR government to a hard line position internally with external threats being used as a rational.
- B. Disintegration of the USSR: nationalistic/ethnic movements lead to internal disorders, civil war, fragmentation of the USSR.
- C. Successful transition of the USSR to a more or less democratic society with a more or less free market economy. In this scenario, Gorbachev or his

successors are able to break the grip of the Communist Party on Soviet politics and its economy.

Rest of the World:

- A. Third World conflicts between nations:** Such conflicts have been common in the past few decades and are probable in the future. They are often driven by religious and/or ethnic differences as well as attempt to control natural resources such as oil. The recent acquisition by Third World countries of ballistic missiles equipped with chemical or nuclear warheads has made much conflicts potentially very dangerous in the future.
- B. Revolutions inside Third World Countries:** These have also been common in the past and are also often driven by ethnic/religious forces.
- C. Terrorism:** Very common in the past and likely to be so in the future. Also often driven by religious/ ethnic factors.
- D. Economic Conflict:** The national security of the U.S. may be effected by a decline of U.S. industry under the impact of intense international competition.

D.3 National Security Priorities

While it is difficult to get an official Secretary of Defense or JCS statement on this subject due to the current national and international political situation, the Task Force had available the results of a number of informal studies, such as the recent DARPA Planning Study. In addition, the White House recently published "National Security Strategy of the United States" (a copy is attached) which lists national security priorities as follows:

- A) Deterring nuclear war**
- B) Deterring conventional war**
- C) Deterring low intensity conflicts/ terrorism**
- D) Countering drug trafficking**

E) Intelligence monitoring and arms control verification

These national security priorities formed the basis for the Task Force assessment.

D.4 Operational Capabilities

The operational capabilities sketched out in this section are suggestive of what might be needed to deal with the future national security scenarios postulated above. In some cases, capabilities of an existing system or systems under development/procurement appear appropriate; in other cases, new capabilities will be needed for which advanced technology will be very important. Tables 1 and 2 summarize the principle R&D issues and the needed technology. A number of notional systems are described in the text to follow. More detailed descriptions are found in Annex 1 to this appendix.

Table 1
Principle R&D Issues

COMPONENT	ISSUES
NUCLEAR WAR DETERRENCE - OFFENSE	
Land-Based ICBMs	<ul style="list-style-type: none">• Survivability• Force size
Bombers (B52s, B1s, B2s?)	<ul style="list-style-type: none">• Penetration capability• Force size• Ability to find concealed mobile targets
Sea-Based SLBMs	<ul style="list-style-type: none">• Future survivability• Force size
Attack Warning - C ³	<ul style="list-style-type: none">• Survivability• Submarine connectivity
NUCLEAR WAR DETERRENCE - DEFENSE	
Conus BMD	<ul style="list-style-type: none">• Effectiveness• Cost

Overseas IRBM Defense	<ul style="list-style-type: none"> • Mobility • Effectiveness • Cost
CONTINGENCY - TERRORISM DETERRENCE (Special Operations)	
INTEL - Attack Warning	<ul style="list-style-type: none"> • Improved ground intelligence
Surveillance - Target ID	<ul style="list-style-type: none"> • Detection of targets concealed in clutter, in adverse weather and at night
C ³	<ul style="list-style-type: none"> • Need for covert communications
Force Projection	<ul style="list-style-type: none"> • Need for stealthy long-range VTOL transport
Force Mobility	<ul style="list-style-type: none"> • Lightweight short-range mobility, including command capability • Rapid sealift for movement and sustainment of forces
CONVENTIONAL WAR DETERRENCE	
Land-TAC Air	<ul style="list-style-type: none"> • Insufficient lift to move current land/air forces • Current forces too heavy, manpower intensive • Insufficient stand-off precision fire power • Fixed-base vulnerability
Sea-Based Forces	<ul style="list-style-type: none"> • Vulnerability of surface fleet to surveillance from space • Defense against LO missiles • Maintenance of ASW superiority
INTEL - Attack Warning	<ul style="list-style-type: none"> • Improved ground intelligence
Surveillance - Target ID	<ul style="list-style-type: none"> • Lack of global coverage • Detection of targets concealed in clutter • Survivability

Table 2.

Needed Technologies

COMPONENT	NEEDED TECHNOLOGY
NUCLEAR WARFARE	
Survivable Attack Warning	<ul style="list-style-type: none"> • High-altitude space surveillance • Satellite survivability
Detection of Mobile Launches	<ul style="list-style-type: none"> • Automatic target recognition
Low-Observable, Cruise-Missile Attack Warning	<ul style="list-style-type: none"> • Economical mobile basing technology
Ballistic Missile Defense	<ul style="list-style-type: none"> • Economical space and ground-based interceptors and targeting
LIMITED WARFARE	
Rapid Sealift for Movement and Sustainment of Forces	<ul style="list-style-type: none"> • Advanced ship technology
Low Observable VTOL Transport	<ul style="list-style-type: none"> • Propulsion structure, sensors, low observables
Wide-Area Surveillance	<ul style="list-style-type: none"> • Same as for conventional warfare
Close-up UAV Surveillance	<ul style="list-style-type: none"> • Same as for conventional warfare
CONVENTIONAL WAR DETERRENCE	
Lightweight EHF Communication Satellites and Terminals	<ul style="list-style-type: none"> • MMIC lightweight, low-power, signal processors
Stand-off Weapons with High Value Target Search and Identification	<ul style="list-style-type: none"> • Automatic target recognizers
Affordable Munitions with "Smart Designators"	<ul style="list-style-type: none"> • Automatic target recognizers
VTOL Tactical Aircraft	<ul style="list-style-type: none"> • Flight control systems, propulsion
Flexible Logistics that can respond to Rapid Movement of Major Forces	<ul style="list-style-type: none"> • Ultra reliable equipment, CASE/computer aided support
CONVENTIONAL WARFARE	
Space-Based, Broad-Area, Air and Surface Surveillance of Low Observable Targets	<ul style="list-style-type: none"> • Light-weight MTI and imaging radar; IR FPAs; energy systems; survivability
Airborne, Local-Area, Air and Surface Surveillance of Low Observable Target	<ul style="list-style-type: none"> • Lightweight, MTI and imaging radar; IR FPAs; laser radar; energy systems; A/J comm links

Detection of Advanced Quiet Submarines	• Acoustic and Non-Acoustic ASW
Sea-Based Surveillance of Low Observable Vehicles	• Advanced radar and IR sensors
Communication to Deeply Submerged Attack Submarines	• Light, efficient lasers for satellites; narrow-band, wide-angle, optical receivers

Deterrence of Nuclear War

This capability is applicable to several of the scenarios outlined above. It obviously applies to a return to a cold war with the USSR, but it also applies to the dangers inherent in an internal breakup of the USSR in which nuclear weapons fall into the hands of the warring factions. It is even applicable to a democratic USSR for such countries can also be aggressors if they decide to engage in empire building.

In addition, and of increasing concern, is the possibility of nuclear war between Third World countries involving U.S. clients.

Some aspects will remain essentially the same:

- Continued evolution of triad to ensure survivability
- Space remains a domain of limited warfare

Some aspects are likely to change:

- Survivable, land-based ICBM force
- Aggressive development of both limited BMD and long term BMD options
- Emphasis on countermeasure approaches to space warfare

Offensive Nuclear Forces

Given the spread of nuclear weapons to Third World countries as well as the extensive modernization by the Soviets of their strategic forces, the U.S. will continue to need nuclear forces for deterrence. The basic issues for the U.S. are the appropriate size, form, and costs of such forces. Reduction in the size of both U.S. and USSR forces may be possible if a START treaty can be negotiated and verified.

The principal components of such a reduced U.S. force might, as they have been in the past, be a Trident SBM fleet, mobile land-based ICBMs, and an air-based compo-

ment, consisting of B-1's with cruise missiles and penetrating B-2 bombers. A modernized attack warning and C3 system is also needed together with intelligence and START verification sensor systems.

In considering the size and structure of the offensive nuclear forces, a number of factors need careful attention in the coming years. The first is the issue of the continued survivability of this force. In the case of the land-based ICBMs, an economical approach for insuring survivability must be implemented, whether by hardening silos, mobility, or defense of silos. In the case of airborne strategic nuclear forces, the continued ability to penetrate Soviet air defenses must be assured by a combination of stealth and electronic countermeasures. Technology and systems are available to address this need. An additional need postulated for airborne forces will be the ability to find concealed mobile strategic launchers. This capability also will be important for deterrence of conventional warfare and is also an area of technology important to understand in connection with the survivability of any U.S. land-based ICBM launchers that may be deployed. Technology is not yet in hand to address these problems.

In the case of the sea-based nuclear forces, a primary issue is that of possible developments in Soviet ASW which might threaten the survivability of these forces.

In addition to the weapon systems described above, the U.S. needs a survivable strategic C³ system including warning of ICBM attack and, under some possible scenarios, in an atmospheric attack, capable of detecting low observable cruise missiles. The technology for the former is available. For the latter, new technology is required.

Defense Against Nuclear Attack

As the result of the SDI program, it appears possible that deterrence enhancing ballistic missile defensive systems may be achievable which are less expensive than the offensive forces that they destroy. If this is the case, then a fundamental rethinking of nuclear deterrence needs to be undertaken. Current proposals for proliferated space-based ballistic missile defenses need to be augmented by studies of similar concepts involving ground-based interceptors. The development of defenses against ballistic missiles is likely to be especially important in defending our allies against Third World nuclear-equipped IRBM forces which are rapidly being developed in a number of countries. For this application, a high level of performance against light attacks is especially important. A transportable ground- or sea-based system may be appropriate for such situations.

The need for developing a CONUS air defense system is considered more problematic in the absence of a good ballistic missile defense. Even if CONUS air defenses are not deployed, there is an important need for a system to warn of a stealthy air attack on our strategic C3 system, bomber bases and submarine bases. Current warning systems do not meet this need.

Unlike offensive nuclear forces, a great deal of new technology will be needed to achieve effective and economic strategic defensive systems.

Deterrence of Conventional Warfare

The experience of the past several decades indicates that conventional warfare, either small scale or on a fairly large scale, is much more probable than nuclear warfare. Only in the cases where nuclear warfare was a likely outcome, i.e., central Europe, was conventional warfare deterred.

Deterrence of conventional warfare is traditionally separated into its land, air and naval elements. The following discussion highlights aspects of such warfare which will likely remain the same and aspects which will likely change.

Land Warfare Circa 2001

Some aspects that will remain essentially the same:

- **Tanks, artillery, and infantry weapons improved but not essentially different**
- **Importance of initial surprise/disruption**
- **Problems with rapid augmentation, deployment and resupply**
- **Dealing with nuclear escalation and CBW**

Some aspects likely to change:

- **Need for "a few good men"**
- **Robust, near-zero CEP standoff weapons - the emergence of "brilliant" systems**
- **Near real-time precision emitter locators and multimode target acquisition systems**
- **Conflict more like soccer than football**
- **Integrated offense/defense capabilities**
- **New trade-offs among mobility, agility, and fire power**
- **Increased autonomy of action by small unit linked via secure, AJ, fail-soft communications**
- **Increase reliance on multi-sensor fusion and near real-time integration of target acquisition and strike**
- **"Extended range mines" and other loiter weapons**
- **More realistic training/training aids**
- **Anti-sensor weapons**
- **The imperative of more flexible, transportable survivable, less-manpower-intensive forces/systems**

Air Warfare Circa 2001

Some aspects that will remain essentially the same:

- **Air superiority and defense suppression crucial**
- **Integration problems with allies**
- **Emphasis on reducing observables**
- **Use of air power in "force Projection," "show the flag" mode**
- **Romance of the single-seat aircraft**
- **Close air support - still an orphan**
- **Relocatable targets - still a problem**
- **Deep Bunkers - still a problem**
- **Penetration of sophisticated defenses - still a challenge**
- **Poorly defined battle lines and threats**
- **Conceptual difficulties with strategic non-nuclear war**

Some aspects likely to change:

- **True all-weather, low-altitude OPS using covert platforms, sensors and digital data bases**
 - **NAV systems closely integrated with penetration & weapon delivery avionics**
- **Increased reliance on multi-sensor fusion and near real-time integration of target acquisition and strike**
 - **More "information" vice more "data"**
- **Growing use of space for targeting and C3**

Naval Warfare Circa 2001

Some aspects likely to remain essentially the same:

- **Air-capable ships to remain the heart of naval power projection**
- **Third-world conflicts require Naval forces**
- **ASW focus remains on Soviets,**
- **Undersea deterrence**

Some aspects likely to change:

- **Trend toward acoustic parity in ASW**
- **Quiet, capable, non-nuclear subs in third world**
- **Dependence on survivable space assets**

Conventional warfare can arise out of a number of the scenarios listed above.

The most common form of conventional warfare will likely be low level revolutionary conflict brought on by political, religious or ethic differences which often manifest themselves in economic discrimination. The causes for revolution can and have been the driver for conflict between Third World countries. Such conflicts have led, in some cases, to major wars involving hundreds of thousands of troops and thousands of armored vehicles.

The question is: What set of U.S. conventional warfare capabilities can best deter such wars in cases where U.S. interests are threatened? Because of the lower explosive power per pound of conventional munitions, the use of expensive long-range ballistic or cruise missiles and aircraft has, to date, not proven economical for conventional weapon delivery as they have for nuclear weapons.

This has led to pre-deployment of our conventional forces in overseas locations. Extensive pre-deployment may not be feasible in the future because of cutbacks in overseas force levels and because of loss of overseas base rights. The value of these deployments goes beyond that of having men and weapons on the scene; it also

Involves an element of deterrence since U.S. forces would be attacked if the country involved were attacked.

In spite of the advantages of overseas deployment of conventional forces, the need to reduce Department of Defense costs will force overseas reductions in manpower. In addition, need to deter conventional warfare in many possible locations around the world argues strongly for rapidly deployable conventional forces based in the CONUS or on the oceans. The basic issue in the design of such forces is that of how significant conventional capability can be rapidly projected to great distances with minimal cost and minimum personnel in combat contact with potential enemy forces.

The current configurations of U.S. heavy land combat forces and tactical air are too heavy for rapid deployment to unprepared locations by available air transport; thus a re-thinking of the design of land and tactical air forces would appear to be required .

The thinking outlined above leads to the following suggested capabilities which may be important in enabling the U . S . to deter conventional war in the future.

- A worldwide intelligence and warning capability able to identify locations of potential conflict, either in the near or far term. This capability needs to depend at least as much on ground-based sources determining political intent as on space-based sensors determining military capability. The current space-based systems are probably adequate, but ground-based intelligence collection needs to be strengthened.
- A worldwide survivable surveillance/ targeting system capable of near real-time observations of land-, sea-, and air-based military forces. Since this system will likely have significant dependence on space, a space surveillance capability and satellite survivability measures will also be needed for its protection. Parenthetically, our current intelligence sensors do not have either the survivability or the real-time coverage needed for intensive conventional combat. A new system is needed to meet this need. It would most likely consist of six to twelve radar satellites in low orbits. Both moving target and imaging capabilities for fixed targets would be desirable. In addition, an infrared search capability for detection of stealth air vehicles would also be desirable. It is possible that a deployable air-based surveillance might be used to augment the space-based system in times of crisis.

- A survivable worldwide anti-jam and low probability of intercept communications system capable of relaying surveillance/targeting information and commands to conventional forces. Although current UHF and SHF satellites provide reliable long-range communications to field forces, protection against uplink jamming and transmission covertness will require a transition to an EHF MilStar system. To provide anti-jam, low probability of intercept (L.P.I) theater area communications to deployed conventional forces, the MilStar system should be augmented with small EHF communication satellites and small lightweight terminals.

- A means of worldwide, rapid (less than 24 hours) delivery of substantial quantities of precision conventional weapons, together with their operators, platforms and targeting systems. Whether this is accomplished by distributed sea-based forces or by long-range air depends on the economics involved. The number of engaged and supporting men required should be kept to a minimum because of the problem of their logistics support. Particular attention needs to be given to keeping the costs of munitions to less than the value of their targets. This means that the use of autonomous smart weapons may have to be limited to high value targets. Lower cost munitions for attacking lesser value targets may have to be directed by "smart" designators which are shared among a number of weapon rounds. Some possibilities for providing these capabilities exist in current programs now under development. In other cases, new systems may be needed. Because of the high costs of developing completely new platforms, there is a high premium on adaptation of existing major platforms or those in production for these new systems. The following possibilities for rapid force projection need to be examined and compared:
 - Use of heavy bombers equipped with stand-off precision weapons for attack of ground targets

 - Use of carrier-based aircraft with precision weapons for ground attack

 - Use of space-based kinetic re-entry weapons for very fast (less than 30 minutes) attack of high value targets. To obtain the necessary precision, such weapons might have to be guided by designator signals sent from a distant platform, perhaps in space.

Use of high-speed (>100 Knots) large (10,000 to 30,000 ton) air cushion vehicles to move newly designed conventional land forces to distant conflicts. The new design for land forces would emphasize high firepower and mobility. Some form of lightly armored low-observable VTOL air vehicle might provide the basis for this force. Indirect fire support might be provided by either air-launched precision standoff weapons or from mobile ground-based rocket launchers. VTOL tactical aircraft operating from dispersed air bases or large ships could provide air cover for deployed land forces.

- Use of submarines to launch precision terminally guided missiles against land targets
- Use of VTOL tactical aircraft operating from temporary air bases or large ships.

An important element in any of these possibilities will be precision munitions which can either find targets by themselves (smart weapons) or be directed by designators operating by men or unmanned air vehicles located in the areas of combat.

- Assurance of Sea Control will continue to be vital to U.S. national security interests for both access to overseas supplies and also to allow the use of seabased force projection. The continued survivability of surface naval fleets will require means of defeating enemy space surveillance systems by active (ASAT) or passive (ECM) means, as well as naval air defense systems capable of coping with low observable missiles. In addition, advanced submarine threats to these sea forces will require extensive improvements in our ASW surveillance systems as well as better quieting of our attack submarines.

Contingency/Terrorism/Drug Trafficking - Special Operations

Contingency operations can utilize many of the conventional war capabilities such as wide-area surveillance and covert communications. In addition, there are several needed capabilities peculiar to this class of military operations:

- A close-up surveillance capability using micro-unmanned air vehicles equipped with elector-optic sensors would be an especially useful adjunct to the longer range space-based surveillance systems.

- Some sort of stealthy long-range high-performance VTOL vehicle is needed for inserting and removing lightly armed special forces.
- A capability for providing special forces with unobtrusive local mobility is also needed. This might take the form of a small-ducted-fan vehicle.

D.5 Cross-Cutting Military Capabilities

Evaluation of the full breadth of the operational capabilities outlined above identifies a number of cross-cutting military capabilities that are common to many of the scenarios and which are critical to accomplishment of U.S. objectives. Cross-cutting military capabilities identified by the Task Force are shown in Figure D-2.

**Figure D-2
Some Cross-Cutting Military Capabilities**

- | | |
|---|---|
| • Precision Standoff and Counter-standoff Weapons | • Real-Time Command Management Systems (Data --> Information) |
| • Stealth & Counter Stealth | • Antijam, Covert Communications |
| • Automatic Target Recognition and Identification | • Active Countering of Enemy Target Acquisition Systems (ECM, ASAT) |
| • Brilliant Systems | • Rapid Response Long-Range Lift for Force Projection |
| • Assured Access to Space | • Lightweight, High-Firepower, Minimally-Manned, Survivable Forces |
| • Night/All-Weather Capability | |
| • Detection of Concealed Targets | |

For example, because our interests are world-wide and we are not likely to have bases in the regions of the world where U.S. interests may be challenged, space systems will become increasingly important. Space systems can provide worldwide, real-

time surveillance to assess the situation. Once military action is deemed necessary, space systems can provide the communications and surveillance to lightweight, high-firepower, minimally-manned, survivable forces projected into the region by our rapid-response, long-range lift capability. Because these space systems are potentially so critical to U.S. operations, we must maintain assured access to space and insure that the capabilities provided by our systems there are protected against projected enemy anti-satellite capabilities.

Because our active forces are likely to be smaller, we must provide them with the technological advantage to survive and prevail against an increasingly technically sophisticated adversary. This includes operating in a situation where stealth may be critical for penetrating enemy defenses and counter stealth capability may be required for timely engagement of enemy threats (e.g., stealthy, sea-skimming missiles that threaten surface ships).

Because potential conflicts will required the use of lightweight, high-firepower, minimally-manned forces, we will need systems which greatly enhance the capability of our forces to find and negate targets quickly, including at night and in all-weather conditions. Thus, real-time command management systems, automatic target recognition and identification systems and the ability to detect targets which are concealed or camouflaged are important to finding and engaging enemy targets. Brilliant autonomous weapon systems and precision standoff weapons will allow our forces to engage the enemy efficiently while minimizing risk if our forces are outnumbered.

D.6 Technology Aggregates

The critical and core technologies identified by the Task Force methodology are shown in Figure D-3 and described below. Some of these technology aggregates are uniquely military, at least at the systems level, and cannot benefit from the national civilian technology base for dual-use technologies. These technologies must be given special consideration in developing an investment strategy, since the DoD must assume total responsibility for their full development and reduction to practice. In addition, for those technologies that are not uniquely military, DoD must establish mechanisms which effectively assist and leverage commercial developments.

Figure D-3
Examples of Critical and Core Technology Aggregates

Critical Technology Candidates

1. INTEGRATED CIRCUITS (DIGITAL, ANALOG, MICROWAVE)
2. ADVANCED SOFTWARE
3. IR FOCAL PLANES (SPACE SURV/TACTICAL TARGETING)
4. LOW VOLUME FLEXIBLE MANUFACTURING
5. AUTOMATIC TARGET RECOG (SIGNAL UNDERSTANDING)
6. COUNTER STEALTH (DIGITAL RADAR)
7. STEALTH TECHNOLOGY
8. SIMULATION/MODELING/TRAINING
9. SIMULTANEOUS ENGINEERING
10. BRILLIANT SYSTEMS
11. HYPERMEDIA INFORMATION MANAGEMENT
12. SATELLITE SURVIVABILITY
13. ANTI-SENSOR WEAPONS
14. PHOTONICS
15. HYPERSONIC KINETIC WEAPONS
16. ADVANCED ROCKET PROPULSION
17. DIRECTED ENERGY WEAPONS
18. HIGH ENERGY - DENSITY MUNITIONS

Core Technology Candidates

1. AIR-BREATHING PROPULSION
2. SIGNAL PROCESSING
3. DATA FUSION
4. FLUID DYNAMICS
5. SOFTWARE ENGINEERING
6. ACOUSTIC DETECTION
7. MICROWAVE TUBES
8. COMPOSITE MATERIALS
9. CONVENTIONAL ARMOR AND ANTI-ARMOR
10. CHEMICAL ROCKET PROPULSION
11. NUCLEAR TECHNOLOGY

#1 Microelectronics (Integrated Circuits: Digital, Analog and Microwave)

Large-scale, integrated digital circuits are critical components of advanced signal processors and automatic target recognizers which process signals from a wide variety of advanced radar and electro-optic sensors. Of nearly equal importance are analog and microwave integrated circuits for use in the front ends of radar, optical, and acoustic sensors. Tremendous advances in sensor capability will be made possible by future integrated circuits having tens of millions of active elements per circuit.

#2 Advanced Software ("Super" CASE)

Advanced digital signal processors, automatic target recognizers, and data fusion systems require very large software systems, which in the past have been costly and difficult to generate. Advances in computer aided software engineering (CASE) promise to greatly improve the efficiency of generating the large, complex, software systems needed in the future.

#3 Infrared Focal Plane Arrays

Infrared sensors are critical to nighttime operations and for strategic surveillance from space. Most current systems employ line arrays of infrared detectors which are scanned over the image. In the future, one or two orders of magnitude improvement in sensitivity can be achieved by sensors employing infrared focal planes having 10 million or more individual detectors in two-dimensional arrays.

#4 Low-Volume Flexible Manufacturing

Military production runs are commonly limited to small numbers, thereby resulting in very high costs and a significant level of defects. Commercial production practices are moving towards low-volume, flexible manufacturing. The adoption of this technology by military system manufacturers should make possible dramatic reductions in costs and defects.

#5 Automatic Target Recognition

A critical capability for both manned and autonomous weapon systems is the ability to automatically recognize targets from the processed data coming from radar, visual, infrared and acoustic sensors. While progress towards this goal has been difficult, new approaches such as advanced artificial neural networks based on the human brain offer hope of substantially enhanced capabilities in the future.

#6 Counter Stealth

It is expected that enemy stealth systems, including third-world missiles, will be a significant threat to U.S. forces in the next decade. A variety of radar, infrared, and acoustic techniques may be able to detect these enemy stealth systems.

#7 Stealth

Low observable (stealth) technologies have been applied successfully to a variety of air vehicles such as the B-2 and cruise missiles. It can be expected that this technology can also be applied to a variety of other military platforms resulting in a very significant increase in the ability of such systems to successfully penetrate enemy defenses without detection.

#8 Simulation/Modeling and Training

Computational and display systems have achieved sufficient capability to permit realistic simulation of proposed new weapon systems and tactics. Such testing will be important for initially testing the value of proposed systems. In addition, such computational and display technology should permit significant advances in the training of operational forces in new and existing systems without extensive field operations.

#9 Simultaneous Engineering

Modern commercial development of new products involves the simultaneous interaction of marketing, research, engineering, and manufacturing functions. The shorter development times and lower costs being achieved by this process in the civilian sector are also achievable in the development and manufacturing of military systems.

#10 Brilliant Systems

The incorporation of advanced automatic target recognizers into autonomous weapon systems offers the possibility of weapons which can search out and attack enemy targets with high precision and effectiveness.

#11 Hypermedia Information Management

Current and future intelligence and surveillance sensors produce very large data bases, often with complex structures and in different locations. It has been difficult in the past for military operators to quickly obtain the information that they need from these data bases. New data management processors (hypermedia) are now making it possible to quickly assemble needed information and represent this information in display formats that facilitate rapid assimilation, understanding and event tracking.

#12 Satellite Survivability

The ability to project military force to deter conventional and limited warfare depends critically on the availability of global surveillance and communications. Space offers the most practical method of achieving such capabilities. Unfortunately, some of our current military space systems are not survivable against current and projected Soviet anti-satellite capabilities. A variety of techniques, such as laser hardening, maneuvering and decoys are potentially useful in increasing the survivability of U.S. military satellites.

#13 / Sensor Weapons

A wide variety of optical and radio frequency sensors are important to tactical warfare. Modest-power, directed energy weapons, (both optical and radio frequency) are capable of disabling such sensors and thereby obtaining a significant military advantage.

#14 Photonics

A variety of applications of optical and electro-optic technologies to defense systems can be identified. These include: (1) the use of light-fiber interconnects for electronic systems and multicomputer processors; (2) the use of analog, parallel, optical processing of two-dimensional arrays of sensor data; (3) the use of arrays of coherent, high-power, laser diodes for laser radar, optical communications and directed energy applications; and (4) the possibility of very high-speed computation by optical computers.

#15 Hypervelocity Kinetic Weapons

At velocities above about 3 kilometers per second, the kinetic energy of a weapon exceeds the energy of an equal weight of explosive. In addition, at such velocities collisions with armor are essentially a hydrodynamic phenomena making it possible for long rods to penetrate even the thickest armor. A variety of means ranging from rocket propulsion and light gas guns to electrically powered projectors and electromagnetic guns are showing promise of achieving the needed velocities.

#16 Advanced Rocket Propulsion

Current chemical rockets are limited to specific impulses of 450 seconds or less. This leads in many cases to the need for multi-stage rockets for important military applications such as space launch and ICBMs. Specific impulses of the order of 1000 seconds in a high thrust-to-weight ratio engine would permit modest-sized, single-stage rockets for many, if not most, applications. These are possibilities for high-performance rocket propulsion.

#17 Directed Energy Weapons

The power and coherence of high power optical sources is steadily increasing. It can be anticipated that power levels will be achieved (in both the U.S. and USSR) which will make possible ground-based laser anti-satellite weapons which will be able to destroy the current generation of low altitude satellites and to severely damage high altitude satellite sensors. With further development a number of tactical applications appear likely. Charged particle beam weapons offer convincing lethality if propagation to useful ranges can be achieved using a system of tolerable size and weight.

#18 High-Energy-Density Munitions

The excitation of azides and other sensitive, high-energy density compounds into metastable states during their initiation offers the possibility of achieving energy releases of 10x to 100x that of current high explosive munitions (e.g, HMX). These new classes of HEDM's offer much greater effectiveness in destroying hardened targets than here-to-fore possible.

#19 Air-Breathing Propulsion

Continued incremental improvements can be expected in the thrust-to-weight ratio and propulsion efficiency of gas turbine propulsion systems. These improvements will be made possible by higher turbine operating temperatures and by better turbine materials.

#20 Signal Processing

The ability of military sensors, such as radar and infrared systems, to detect targets in clutter is dependent on high-speed digital signal processing. Over the next decade

the speed of such processors will likely improve by one or perhaps two orders of magnitude. This will permit substantial improvements in sensor performance.

#21 Data Fusion

Significant improvements in computation speed and in the size of electronic memories are under development. These advances will be important for greatly improved fusion of military intelligence and operational data. Such improved data bases are important for future decisions aids systems that support military commanders.

#22 Fluid Dynamics

Continued incremental advances can be expected in reducing the drag of aerodynamics and ocean military vehicles. These advances are being achieved through improved computer simulation made possible through the speed of supercomputers.

#23 Software Engineering

The advance in the productivity of software production has been modest as compared with advances in computer power. Continued incremental improvements can be expected in this field through the use of CASE (Computer-Aided Software Engineering).

#24 Acoustic Detection

Acoustic detection is very important for antisubmarine warfare as well as for land combat. Dramatic decreases in the noise levels of contemporary submarines require an entirely new approach in acoustic submarine detection. Distributed acoustic arrays and improved signal processing offer opportunities for significant improvements in the performance of acoustic detection systems. In land warfare, acoustic systems offer the opportunity for detection of land and air vehicles that are beyond line-of-sight.

#25 Microwave Tubes

Microwave tubes continue to be important for a number of defense systems where high peak power (megawatts) and average rf power (hundreds of kilowatts) are required. In addition, such devices also can provide very high percentage bandwidth amplifiers for ECM applications.

#26 Composite Materials

Composite materials employing high-strength fibers embedded in a polymer binder will be of increasing importance for military vehicle structural applications where the strength-to-weight ratio is important. These materials already offer performance markedly better than metal alloys at low temperature. Metal matrix composites hold the potential for high strength-to-weight at high temperatures.

#27 Conventional Armor and Anti-Armor

Continued incremental improvements can be expected in conventional armor applications involving protection against conventional munitions. Similarly, incremental improvements in the design of conventional armor penetrators can be expected.

#28 Chemical Rocket Propulsion

While relatively little improvement in performance (Isp) of chemical rockets can be expected due to thermodynamic limitations, there are a number of opportunities to improve reliability and lower the cost of such rockets through incremental technological changes.

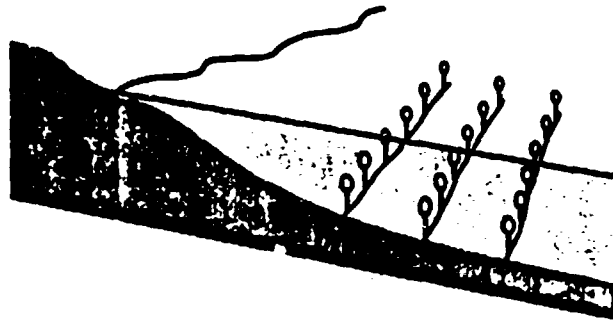
#29 Nuclear Technology

The field of nuclear weapon and reactor technology is fairly mature; however, continued improvements can be expected in the areas of reliability, safety, size and weight.

Annex 1
Notional Systems

	<u>System</u>	<u>Function</u>	<u>Comments</u>
A.	Space-Based Broad-Area Surveillance and Target Identification	Target Acq.	New Capability
B.	ASW Broad-Area Surveillance	Target Acq.	10 to 1 increase in Area Coverage
C.	Anti-Jam L.P.I. Communications	C3	New Capability
D.	Air-Launched Standoff Precision Weapons (B-2 or A-12 based)	Forced Projection	New Capability
E.	Space-Launched Precision Kinetic Weapons	Force Projection	New Capability
F.	Lightweight Land Combat System	Force Projection	New Capability
G.	VTOL Tactical Air	Air Supremacy - Air Defense	New Capability
H.	High-Speed Surface Effect Ship	Lift for Land Force	New Capability
I.	VTOL Special Forces Transport	Lift	New Capability
J.	Anti-Stealth Air Defense	Defense of Ships and CONUS?	New Capability
K.	Tactical BMD	Defense	New Capability
L.	ASAT	Space Control	New Capability

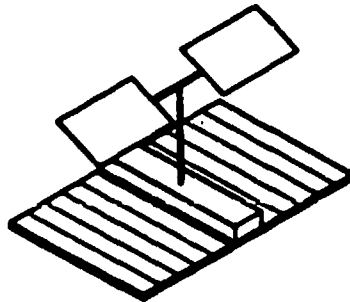
A. ASW BROAD AREA SURVEILLANCE



- **CAPABILITY:**
 - DETECTION OF ADVANCED DESIGN SUBMARINES WITH REDUCED ACOUSTIC SIGNATURES
- **CONCEPTUAL DESIGN:**
 - DISTRIBUTED ACOUSTIC OCEAN BOTTOM ARRAYS FOR DETECTION
 - ACTIVE ACOUSTICS FOR LOCALIZATION

[NEW CAPABILITY]

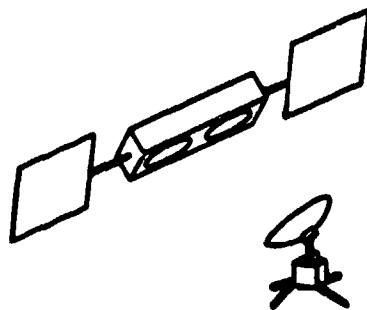
B. SPACE BASED SURVEILLANCE AND TARGET IDENTIFICATION



- **CAPABILITY:**
GLOBAL SURVEILLANCE OF: AIR VEHICLES
SHIPS
GROUND TARGETS
- **CONCEPTUAL DESIGN:**
 - 6-10 RADAR SATELLITES
 - 400-1000 MILE ALTITUDE
 - 500 m² L/S BAND PHASED ARRAY
 - MOVING TARGET, IMAGING RADAR, AND IR SENSORS
 - 2500-5000 kg WEIGHT

[NEW CAPABILITY]

C. ANTI-JAM L.P.I. SATELLITE COMMUNICATIONS



• CAPABILITY:

GLOBAL AJ AND LPI COMMUNICATIONS FOR CONVENTIONAL WARFARE
LOCAL CIRCUITS, ~30-2400 BITS PER SECOND CIRCUITS PER SATELLITE

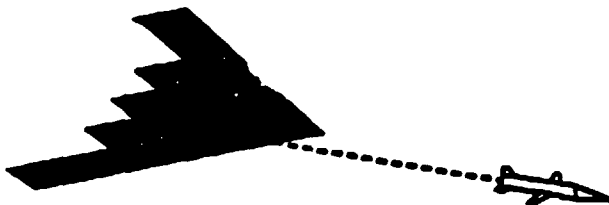
• CONCEPTUAL DESIGN:

- ADD TO MILSTAR SATELLITES
- 10-20 LIGHTWEIGHT SATELLITES IN HIGH ORBITS
- EHF MILSTAR WAVEFORMS AND FREQUENCIES
- 250 kg WEIGHT
- MOBILE TERMINALS — ANTENNAS 0.3-2 m DIAMETER

[10:1 INCREASE IN CAPACITY FOR SAME COST]

D.

PRECISION STAND-OFF MISSILE (Air Launched From B-52s, B-1s, B-2s, A-12s)



• CAPABILITY:

- GLOBAL FORCE PROJECTION FROM CONUS (Or Navy Carriers)
- 100-300 MILE STAND-OFF FROM GLOBAL RANGE AIRCRAFT
- 1.0 m C.E.P.

• CONCEPTUAL DESIGN:

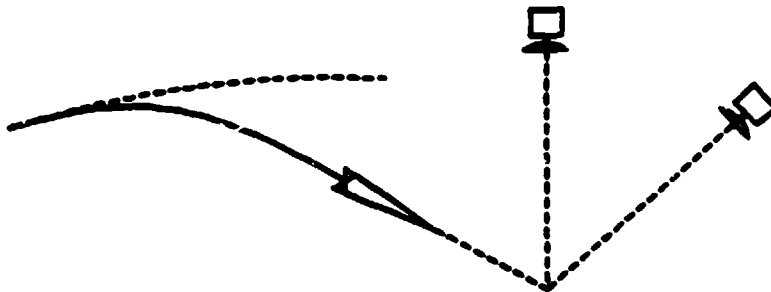
ROCKET BOOSTED QUASI-BALLISTIC TRAJECTORY

TWO VERSIONS: 500 kg AUTONOMOUS SAR/LASER RADAR ATR
GUIDANCE FOR HIGH VALUE TARGETS

100 kg DESIGNATED VERSION FOR LOWER VALUE TARGETS,
MM WAVE AND LASER DESIGNATION BY MICRO UAV
CONTROLLED FROM GROUND OR LAUNCH AIRCRAFT

[NEW CAPABILITY]

E. SPACE-TO-SURFACE PRECISION KINETIC WEAPON



• CAPABILITY:

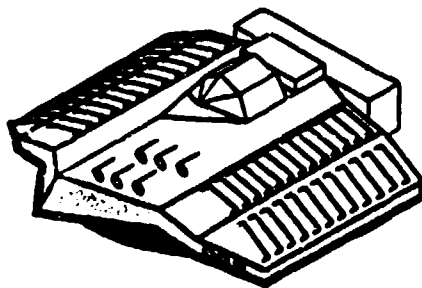
- GLOBAL RANGE ATTACK OF HIGH VALUE TARGETS
- 10^9 JOULE KINETIC KILL
- 1-5 m C.E.P.

• CONCEPTUAL DESIGN:

- 100-1000 100 kg RE-ENTRY VEHICLES IN 400 MILE ALTITUDE ORBITS
- RVs GUIDED BY BISTATIC MM WAVE DESIGNATORS ON RADAR SATELLITES

[NEW CAPABILITY]

F. LIGHTWEIGHT LAND COMBAT SYSTEM



• CAPABILITY:

- LOW OBSERVABLE LAND COMBAT WEAPON SYSTEM
- VTOL OPERATION - 100 KNOTS SPEED
- 100 ROUNDS ROCKET PROPELLED PRECISION KINETIC MUNITIONS

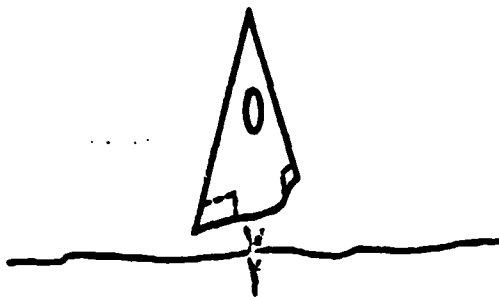
• CONCEPTUAL DESIGN:

- DUCTED FAN LIFT AND PROPULSION
- 10,000 lb WEIGHT
- LASER RADAR TARGETING

[NEW CAPABILITY]

G.

VTOL TACTICAL AIRCRAFT



• **CAPABILITY:**

- VTOL TACTICAL AIR OPERATIONS WITHOUT DEPENDENCE ON LARGE AIR BASES

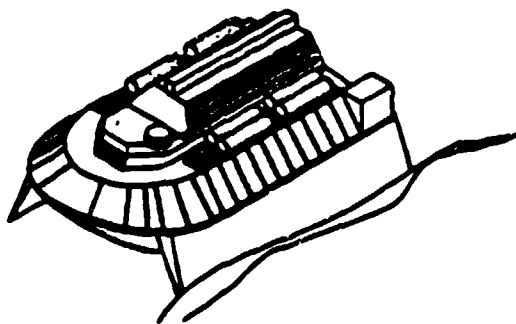
• **CONCEPTUAL DESIGN:**

- CURRENT PROPULSION SYSTEMS PROVIDE THRUST WHICH EXCEEDS WEIGHT OF TACTICAL AIRCRAFT
- AIRCRAFT VERTICALLY ORIENTED FOR TAKEOFF AND LANDING — NO LANDING GEAR OR RUNWAYS NEEDED, MOBILE UNITS PROVIDE LOGISTICS

[NEW CAPABILITY]

H.

HIGH SPEED SURFACE EFFECT SHIP



• **CAPABILITY:**

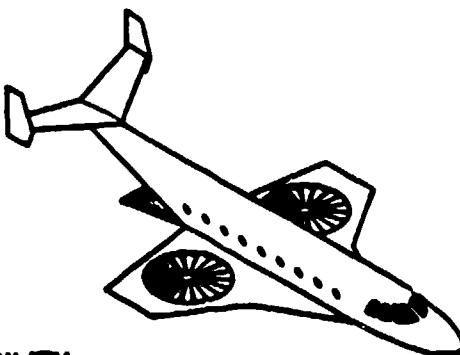
TRANSPORT 10,000 TONS OF CARGO 5,000 MILES AT 100 KNOTS

• **CONCEPTUAL DESIGN:**

- SURFACE EFFECT LIFT
- GAS TURBINE PROPULSION AND LIFT

[NEW CAPABILITY]

I. VTOL SPECIAL FORCES TRANSPORT



• CAPABILITY:

- TRANSPORT OF 10-20 SPECIAL FORCES TROOPS
- RADIUS OF OPERATIONS: 1000 MILES
- 180 KNOTS SPEED
- SMALL FIELD LANDING/TAKEOFF CAPABILITY

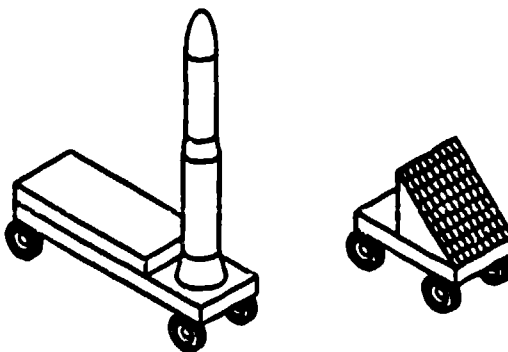
• CONCEPTUAL DESIGN:

- DUCTED FAN LIFT AND PROPULSION
- AVIONICS FOR NIGHT, LOW ALTITUDE OPERATIONS
- LOW OBSERVABLE TREATMENT

[NEW CAPABILITY]

J.

TACTICAL BMD



• CAPABILITY:

- MOBILE BMD FOR DEFENSE AGAINST IRBMs WITH RANGES UP TO 2000 km

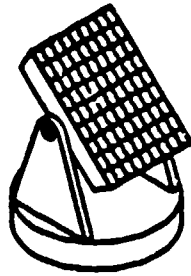
• CONCEPTUAL DESIGN:

- X-BAND PHASED ARRAY RADAR FOR SEARCH AND MIDCOURSE GUIDANCE
- BOOSTER LAUNCHES MULTIPLE KINETIC KILL WEAPONS WITH IR TERMINAL GUIDANCE

[NEW CAPABILITY]

K.

LASER ASAT



- **CAPABILITY:**
 - **DESTROY SATELLITES WITH ALTITUDES UP TO 1000 MILES**
- **CONCEPTUAL DESIGN:**
 - **DIODE LASER ARRAY 3 x 3 m**
 - **POWER LEVELS - (2-5)MW - 25% EFFICIENCY**
 - **ATMOSPHERIC COMPENSATION BY PHASING OF ARRAY SUBAPERTURES**

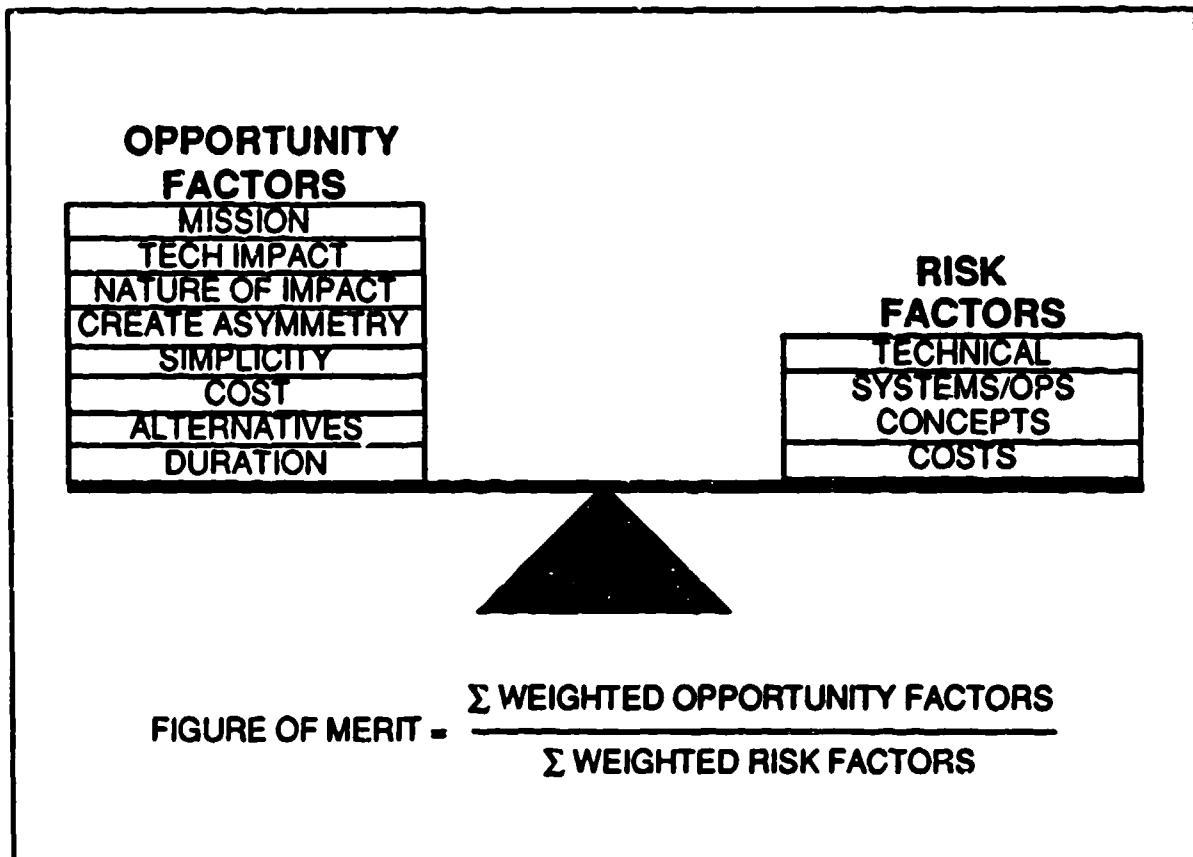
[NEW CAPABILITY]

APPENDIX E

Prioritization of Critical Technologies

Since the opportunities for doing important research and development on critical technologies will almost certainly exceed available resources, a prioritization mechanism is needed for the development of an investment strategy. A methodology that includes an assessment of both opportunities and risks in the ranking of technologies, developed and recommended in the 1981 DSB Summer Study, was found to be of great value. The rating factors for this methodology are shown in Figures E-1 and E-2.

Figure E-1
Technology Assessment Methodology



**Figure E-2
Technology Assessment Criteria**

		HIGH (3PTS)-GREEN	MED (2PTS)	LOW (1PTS)-RED
A. IMPACT OR OPPORTUNITY	1. MISSION VALUE	STRATEGIC NUCLEAR (OFFENSE AND DEFENSE), SPACE	TACTICAL NUCLEAR TACTICAL CONVENTIONAL	GENERAL SUPPORT AND LOGISTICS
	2. TECH-IMPACT ON MISSION SYSTEM	REASON 'D ETRE' - SYSTEM WOULD NOT EXIST W/O THIS PARTICULAR TECHNOLOGY; ORDER OF MAGNITUDE IMPROVEMENT	TECHNOLOGY SIGNIFICANTLY AFFECTS PERFORMANCE	GENERALLY AFFECTS PERFORMANCE
	3. Pervasiveness	ACROSS MANY MISSIONS AND SYSTEMS	SUPPORTS ONE MISSION OR CLASS OF SYSTEMS	SPECIFIC TO ONE OR A FEW SYSTEMS
	4. NATURE OF IMPACT	REVOLUTIONARY	SIGNIFICANT CHANGE	EVOLUTIONARY
	5. LEVERAGE (EXPLOITS US/SSR ASYMMETRY)	GIVES CAPABILITY TO REDRESS SHORT TERM IMBALANCE (E.G. A PRESENT OR PROJECTED SYSTEM)	REDRESSES LONG TERM IMBALANCES	US/SSR FORCE STRUCTURES ARE COMPATIBLE IN SIZE AND SOPHISTICATION FOR NOW AND FUTURE
	6. SIMPLICITY	COULD RADICALLY SIMPLIFY WEAPONS	MODERATE INFLUENCE	LITTLE IMPACT
	7. COST	COULD RADICALLY REDUCE COST	MODERATE INFLUENCE	LITTLE IMPACT
	8. EXISTENCE OF ALTERNATIVES	NO VIABLE ALTERNATIVES	BRUTE FORCE COULD CREATE AN ALTERNATIVE	ONE OR MORE EXIST
	9. DURATION OF IMPACT	A LOWER IN COST COULD EXIST IN > 10 YEARS	IN < 10 YEARS	IN < 5 YEARS
B. TECHNICAL RISKS	1. MATURITY OF TECHNOLOGY	APPLICATION UNCERTAIN, EMERGING	STILL DEVELOPING	MATURE TECHNOLOGY
	2. TECHNOLOGY BASE	A "GAP" EXISTS, REQUIRES NEW KNOWLEDGE BASE	A "GAP" EXISTS, BUILDS ON CURRENT KNOWLEDGE BASE	PRINCIPAL TECHNOLOGIES ARE PRACTICED IN DoD COMMUNITY
	3. INNOVATION POTENTIAL	DoD S&S ADD LITTLE SINCE THIS IS AN AREA OF STRONG TECHNOLOGY COMPETITION	MORE EVOLUTIONARY IN NATURE	DoD APPROACH PROVIDES A SIGNIFICANT PERFORMANCE ADVANTAGE
C. SYSTEM/ OPERATIONAL CONCEPT RISKS	1. MISSION/SYSTEM RELATED RISKS	SYSTEM CONCEPT NOT IN EXISTENCE TODAY	REQUIRES EXTENSIVE APPLICATION SUPPORT, NEW SYSTEM CONCEPT TO DoD BUT WHICH IS IN EXISTENCE	SIMILAR CONCEPTS OR SYSTEMS TO CURRENT DoD
	2. POLITICAL BUREAUCRATIC ENVIRONMENT	DEPENDENT ON ASSETS CONTROLLED BY EXTENSIVE INFRASTRUCTURE, REQUIRES CHANGE IN ARMS CONTROL AGREEMENT	REQUIRES REPLACEMENT OF MATURE TECH OR CREATION OF AS YET UNPERCEIVED NEEDS	REQUIRES EXTENSION OF EXISTING SYSTEM TREATIES/ INFRASTRUCTURE
	3. LEVEL OF OPERATIONAL/ SUPPORT IMPACT	REQUIRES SIGNIFICANT SHIFT IN PERSONNEL AND IN SUPPORT INFRASTRUCTURE	REQUIRES SOME UNIQUE SKILLS/ SUPPORT	CAN TAP AVAILABLE PERSONNEL AND /OR SUPPORT
D. R&D COSTS	1. MANUFACTURING BASE	CAPITAL INTENSIVE AND REQUIRES SIGNIFICANT S&S EXPENDITURE. KEY PROCESSES MUST BE DEVELOPED	REQUIRES UNIQUE FACILITY, PROCESSES/ EQUIPMENT KNOWN TO EXIST	BUILDS ON AVAILABLE BASE
	2. UNIQUENESS OF MILITARY AID	UNIQUELY MILITARY, HIGH R&D COST TO DoD	SELECTED ASPECTS OF TECHNOLOGY ARE UNIQUELY MILITARY	PRIMARILY COMMERCIAL, DoD EXPLOITS COMMERCIAL DEVELOPMENTS
E. SUMMARY		ORDER OF MAGNITUDE IMPACT LOWER RISK, OPPORTUNITIES TENDING TOWARD GREEN	MIXED	IMPACT UNCLEAR/EMERGING A. NOT CLEARLY RED B,C,D. TENDING TOWARD RED

The opportunity factors include:

- 1) mission value, where the highest rating is placed on those technologies that support strategic missions;
- 2) an assessment of the technical impact of the technology on the mission or system, from enabling (high) to general improvement in performance (low);
- 3) pervasiveness, where higher ratings are assigned to those technologies that have application across many missions and/or systems;
- 4) an assessment of the nature of the impact of the application that the technology supports, from revolutionary (high) to evolutionary (low);
- 5) an assessment of leverage relative to an adversary (e.g., exploiting an asymmetry), with the highest weight given to a technology which potentially redresses a short-term force imbalance;
- 6) an assessment of the capability of the technology for simplifying the execution of a military mission;
- 7) an assessment of the capability of the technology to reduce the cost of executing a military mission;
- 8) an assessment of the degree to which there exist alternatives to using the technology in accomplishing the mission; and,
- 9) an assessment of the duration of the impact before new technologies can be introduced to affect the balance of forces, (i.e., how long would it take an adversary to negate the impact of the new technology by introducing his own countermeasures or similar technology?)

The risk factors are based on assessments of technological risks, system/operational concept risks, and cost risks. The technological risks include:

- 1) an assessment of the maturity of the technology;
- 2) an assessment of the degree to which the technology is practiced in the DoD technology base; and,

- 3) an assessment of the potential for innovation, with a low risk rating going to a technology with many possible paths to success.

The system/operational concept risks include:

- 1) an assessment of mission/system-related risks (Is the operational concept similar to those in current DoD use or is a comparable system in existence?);
- 2) an assessment of risks associated with the political or bureaucratic environment, ranging from simple extension of existing systems, treaties, and infrastructure to displacement of major current infrastructure or renegotiation of treaties; and,
- 3) an assessment of the risk associated with operational support; that is, can the operation of this system/concept tap available personnel (low risk) or does support of the system require a major shift in personnel and supporting infrastructure.

R&D cost risks include:

- 1) an assessment of the extent to which a manufacturing base exists to produce a system based on the new technology; and,
- 2) an assessment of the uniqueness of military R&D on this technology, where low risk is assigned to a technology where DoD can exploit commercial development and high risk is assigned to those developments that are uniquely military, (and therefore of high cost to DoD).

Each of the opportunity and risk factors may be weighted based on an assessment of its relative importance and/or emphasis desired. The opportunity or risk rating of a technology is obtained by summing the products of the weighting factors and 2 raised to a power equal to the rating given each factor ($i-3$). Having obtained the risk and opportunity factors in this manner, the figure of merit for the technology is obtained by dividing the opportunity rating by the risk rating. An example of this process applied to infrared focal planes is shown in Figure E-3.

This rating system has been applied to the critical technology candidates, and the ratings for each are summarized in Figure E-4.

Figure E-3

Infrared Focal Planes

<u>WI</u>	<u>IMPACT OR OPPORTUNITY</u>	
2.5	MISSION VALUE	3
2.0	TECHNICAL IMPACT ON MISSION/SYSTEM	3
1.5	PERVASIVENESS	3
2.0	NATURE OF IMPACT	2
2.0	LEVERAGE (EXPLOITS ENEMY ASSYMETRY)	3
1.5	SIMPLICITY	1
2.0	COST	1
2.5	EXISTENCE OF ALTERNATIVES	2
1.5	DURATION OF IMPACT	2
	<u>RISK FACTORS</u>	
2.0	MATURITY OF TECHNOLOGY	2
1.5	TECHNOLOGY BASE	2
2.5	INNOVATION POTENTIAL	1
	<u>SYSTEM/OPERATIONAL CONCEPT RISKS</u>	
2.0	MISSION/SYSTEM RELATED RISKS	2
2.5	POLITICAL BUREAUCRATIC ENVIRONMENT	1
2.5	LEVEL OF OPERATIONAL SUPPORT IMPACT	2
	<u>R&D COSTS</u>	
2.0	MANUFACTURING BASE	2
2.0	UNIQUENESS OF MILITARY R&D	2
	OPPORTUNITY RATING*	95 HIGH
	RISK RATING*	60 MED
	TECHNOLOGY FIGURE OF MERIT	1.583
		* HIGH (88-140)
		MED (56-87)
		LOW (35-55)

**Figure E-4
CRITICAL TECHNOLOGY AGGREGATES**

IN ORDER OF FIGURE OF MERIT			
		OPPORTUNITY	RISK FOM
1	INTEGRATED CIRCUITS (DIGITAL, ANALOG, MICROWAVE)	110	56 1.96
2	ADVANCED SOFTWARE (CASE)	83	43 1.93
3	IR FOCAL PLANES (SPACE SURV/TACTICAL TARGETING)	95	60 1.58
4	LOW VOLUME FLEXIBLE MANUFACTURING	60	39 1.54
5	AUTOMATIC TARGET RECOG (SIGNAL UNDERSTANDING)	84	55 1.53
6	COUNTER STEALTH (DIGITAL RADAR)	87	61 1.43
7	STEALTH TECHNOLOGY	90	67 1.34
8	SIMULATION & MODELING	77	61 1.26
9	SIMULTANEOUS ENGINEERING	67	54 1.24
10	BRILLIANT SYSTEMS	101	82 1.23
11	HYPERMEDIA INFORMATION MANAGEMENT	60	50 1.20
12	SATELLITE SURVIVABILITY	79	66 1.20
13	HYPERSONIC KINETIC WEAPONS	77	65 1.18
14	PHOTONICS	86	74 1.16
15	ADVANCED ROCKET PROPULSION	85	78 1.09
16	ANTI-SENSOR WEAPONS	91	89 1.02
17	HIGH ENERGY DENSITY MUNITIONS	91	98 0.93
18	DIRECTED ENERGY WEAPONS	103	118 0.87

**Figure E-4
CRITICAL TECHNOLOGY AGGREGATES**

IN ORDER OF OPPORTUNITY			
		OPPORTUNITY	RISK FOM
1	H INTEGRATED CIRCUITS (DIGITAL, ANALOG, MICROWAVE)	110	56 1.96
2	H DIRECTED ENERGY WEAPONS	103	118 0.87
3	H BRILLIANT SYSTEMS	101	82 1.23
4	H IR FOCAL PLANES (SPACE SURV/TACTICAL TARGETING)	95	60 1.58
5	H ANTI-SENSOR WEAPONS	91	89 1.02
6	H HIGH ENERGY DENSITY MUNITIONS	91	98 0.93
7	M STEALTH TECHNOLOGY	90	67 1.34
8	M COUNTER STEALTH (DIGITAL RADAR)	87	61 1.43
9	M PHOTONICS	86	74 1.16
10	M ADVANCED ROCKET PROPULSION	85	78 1.09
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14	M SIMULATION & MODELING	77	61 1.26
15	M HYPERSONIC KINETIC WEAPONS	77	65 1.18
16	M SIMULTANEOUS ENGINEERING	67	54 1.24
17	M LOW VOLUME FLEXIBLE MANUFACTURING	60	39 1.54
18	M HYPERMEDIA INFORMATION MANAGEMENT	60	50 1.20

**Figure E-4
CRITICAL TECHNOLOGY AGGREGATES**

IN ORDER OF RISK

		OPPORTUNITY	RISK	FOM
1	L LOW VOLUME FLEXIBLE MANUFACTURING	60	39	1.54
2	L ADVANCED SOFTWARE (CASE)	83	43	1.93
3	L HYPERMEDIA INFORMATION MANAGEMENT	60	50	1.20
4	L SIMULTANEOUS ENGINEERING	87	54	1.24
5	L AUTOMATIC TARGET RECOG (SIGNAL UNDERSTANDING)	84	55	1.53
6	M INTEGRATED CIRCUITS (DIGITAL, ANALOG, MICROWAVE)	110	56	1.96
7	M IR FOCAL PLANES (SPACE SURV/TACTICAL TARGETING)	95	60	1.58
8	M COUNTER STEALTH (DIGITAL RADAR)	87	61	1.43
9	M SIMULATION & MODELING	77	61	1.26
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11	M SATELLITE SURVIVABILITY	79	66	1.20
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16	M ANTI-SENSOR WEAPONS	91	89	1.02
17	H HIGH ENERGY DENSITY MUNITIONS	91	98	0.93
18	H DIRECTED ENERGY WEAPONS	103	118	0.87

APPENDIX F

Technology-Driven Paradigm Shifts That Could Impact the DoD

SOFTWARE

- REUSABLE, UNDERSTANDABLE, MODIFIABLE SOFTWARE--OBJECT-ORIENTED COMPUTING
- DATABASE-CENTERED vs. TOOL-CENTERED SYSTEM DEVELOPMENT
- COMPUTER-AIDED SOFTWARE ENGINEERING - CASE
- FACTORY C³ - MORE IMPORTANT THAN ROBOTICS TO THE FACTORY OF THE FUTURE

MICROELECTRONICS

- FAST TURN-AROUND MINI-FABS vs. MEGA-FABS -- CHANGE IN THE CAPITAL STRUCTURE OF THE SEMICONDUCTOR INDUSTRY
- PROCESS TRANSPARENT DESIGN, OBJECT-ORIENTED DESIGN AND CONCURRENT ENGINEERING
- PACKAGING AS A SYSTEM PERFORMANCE DRIVER
- MEMORY-DOMINATED LOGIC CHIPS
- USER-CONFIGURABLE CHIPS--FIELD-CONFIGURABLE GATE ARRAYS, ETC.
- SOI WAFERS REQUIRED FOR SUB-HALF MICRON VLSI
- APPLICATION SPECIFIC SUBSYSTEMS--EMERGENCE OF SPECIALIZED, INTEGRATED MODULE/SUBSYSTEM MANUFACTURING INFRASTRUCTURE (CHANGE IN THE MANUFACTURING STRUCTURE OF PORTIONS OF THE ELECTRONIC EQUIPMENT INDUSTRY)

INFORMATION SYSTEMS

- **COMPUTERS AS KNOWLEDGE ACCESS TOOLS VERSUS COMPUTATIONAL TOOLS--HYPERMEDIA**
- **INFORMATION "UTILITIES"--AGENT-CENTERED vs. TOOL, MENU, ETC., VIEW OF COMPUTING--DECLINE OF "PROGRAMMING?"**
- **COMPUTER SECURITY AS AN ARCHITECTURAL DRIVER**
- **COMPUTER-BASED ELECTRONIC BOOKS**
- **"INTELLIGENT" ASSISTANTS: PILOT'S ASSOCIATE, COMMANDER'S ASSOCIATE, MANAGER'S ASSOCIATE, ETC.**
- **SELF-TAUGHT, DATA-DRIVEN COMPUTATIONAL SYSTEMS USING NEURAL NETWORKS**
- **NEAREST NEIGHBOR INTERCONNECT ARCHITECTURES (CELLULAR AUTOMATA) vs. STANDARD CHIP WIRING TECHNIQUES**
- **EMERGENCE OF DOMAIN-SPECIFIC INFORMATION UTILITIES--KNOWLEDGE IN MACHINE EXECUTABLE FORM**
- **TRANSPARENT PARALLELISM**

TRAINING

- **JUST-IN-TIME TRAINING**

SYSTEMS

- **"BRILLIANT" vs. "SMART" SYSTEMS -- "BRILLIANT" SYSTEMS ARE CAPABLE OF MANAGING THEIR OWN MISSIONS IN THE PRESENCE OF UNCERTAINTY**
 - **FACTORY, MILITARY**
 - **MAY HAVE APPLICATION TO BUSINESS MANAGEMENT -- SYSTEMS "OPERATE" THE FIRM WHILE PEOPLE DESIGN THE STRATEGIES AND MISSIONS**
- **ALL-DIGITAL RADAR**
- **"FAIL-SOFT" ELECTRONICS**
- **WIRELESS LOCAL AREA NETWORKS**
- **POCKET SATELLITE TERMINALS**
- **"VIRTUAL" FACTORIES/CONCURRENT ENGINEERING**

APPENDIX G
Application of 7-Point Criteria to the Precision Optical Industry

1. Defense Test

How important is the product or Service to DoD?

Precision optical components are essential to DoD.

- Is the product or Service essential for the development, production, or support of current or future defense systems?

Precision optical components, both visible and IR, are critical elements in every major defense system: aircraft, ships, tanks, howitzers, missiles, and night vision device.

- How important is the system in a conflict?

In the aggregate, these systems constitute most of the US offensive and defensive capability and are absolutely essential to US military capability.

2. Technology/Manufacturing Process Test

What is the rate of change of the technology and manufacturing process?

The low end, high volume market has a relatively low rate of change. However, many military applications that require sophisticated designs and associated manufacturing process have the potential for the introduction of innovative designs and processes (moderate rate of change). The IR segment of the industry has a high potential for introduction of new materials, designs and manufacturing processes. The introduction of flexible advanced manufacturing technologies could have a dramatic impact on the industry by reducing the dependence on skilled opticians.

3. Reconstitution/Surge Capacity Test

What percentage of current DoD production requirements can be met from domestic (US, Canadian) sources?

About 50% of current DoD requirements (DoD requirements average 100,000 components/month) are met from domestic sources.

What is the capability of domestic sources (primes, sub-tier vendors, material suppliers) to meet surge and mobilization requirements?

Industry and DoD studies show that domestic sources could not meet surge requirements (defined as a doubling of defense output - 100% increase - in 6 months) or mobilization (a quadrupling of defense output - a 300% increase - in 12 months). Estimates suggest that the industry could achieve a 50% increase at the end of 6 months and an 80% increase at the end of one year. If the industry continues to deteriorate reconstitution of capacity will become increasingly difficult because of a lack of critical skills.

3. Reconstitution/Surge Capacity Test - continued

- At what percent do they operate today?
Domestic sources operate at about 60% of their practical capacity utilization (practical capacity is 3.8 M elements/year). Of the 2.3 M units produced annually, about 600 K are for defense at 1.7 M for commercial use.
- How long would it take to ramp up to maximum practical capacity?
It would take an average of 43 weeks to ramp up to practical capacity.
- What factors could affect the time required to reach practical capacity?
Factors affecting time to reach practical capacity are availability of skilled opticians and of shift supervisors for 2nd and 3rd shift operation, and long lead times for materials including optical glass, grinding and polishing compounds, and coating materials.
- What factors affect conversion of commercial capacity to defense capacity?
Factors limiting conversion of commercial capacity to defense capacity are availability of skilled opticians - most have skills adequate for less demanding commercial work and may be unable to meet requirements for defense production. The industry has suffered a 50% decline in work force over the last decade and most of the highly skilled workers are reaching retirement with few replacements available; - limited testing, inspection and vacuum coating equipment - DoD requires much more metrology, and testing under humidity, salt, and vibration conditions than commercial products; - and availability of special glass blends required by DoD.

4. Vulnerability Test

How likely is loss of access to foreign sources?

Loss of access to foreign sources is unlikely.

- Under current conditions?

It is very unlikely that there would be any loss in foreign sourced materials, components, or equipment under present conditions. Lead time for some production equipment could increase if Japanese suppliers are encouraged to favor their domestic producers.

- Under what conditions requiring surge or mobilization?

Some loss of access could occur under surge or mobilization conditions depending on the scenario but a total cutoff is unlikely.

How acceptable is the security risk associated with furnishing material, component or sub-assembly specifications to foreign suppliers?

There is little risk associated with material or component specifications for those items currently sourced abroad.

5. Linkage Test

How dependent are the domestic sources of foreign suppliers?

Domestic sources are heavily dependent on foreign suppliers.

- For production equipment?

Domestic producers rely heavily on imported production equipment, spare parts and related Services. Most of their production equipment comes from West Germany, England and Japan. Therefore, dependency will likely increase.

- For materials or components?

Seventy percent of the glass used by US producers is now imported. An exception is infrared optical material. US infrared optical material producers are among the best in the world and supply US demand. Over 50% of DoD's requirements for finished optical components are satisfied through imports primarily from Taiwan, Japan and Singapore.

How threatened are the domestic sources?

The competitive outlook is mixed. US firms have mostly given up the commodity optical element business and reoriented to higher value-added products where their superior design and engineering skills provide advantage. US firms are becoming more dependent on DoD business with its associated uncertainty. The domestic materials supplier base is down to two companies to provide glass or casting for visible wavelengths. The infrared sector-components and suppliers are strong.

- Is DoD the major customer?

DoD is the domestic industry's largest customer accounting for about 42% of sales. The industry's increasing reliance on a defense market makes investment in modern production equipment harder to justify and DoD volatility makes retention of skilled personnel more difficult. DoD off-shore procurements could result in technology transfer to the Far East.

- How competitive are the domestic sources?

- Imports?
- Market share?
- Capital investment?
- Productivity?
- Process R&D?

Domestic sources are losing market share. US production of about 2.3 M units accounts for about 2% of total US consumption. On a value basis, the US producers' share is estimated at between 30%-40% because US firms participate in highly specialized low-volume markets. Capital investment is up, productivity is declining, and process R&D investment is very small. US firms rate themselves most competitive in technology (design and engineering) and least competitive in cost. About 70% of the total cost of an optical element is labor and underlies the massive displacement of American producers from the commodity optical market by Far East producers. The US position in infrared optical components and materials is very strong, although subject to severe environmental protection concerns.

5. Linkage Test - continued

- How many domestic sources are there?
There are 9 domestic firms that represent 85% of total US capacity.
- How robust is the domestic vendor/supplier base?
There is only a single domestic source of optical glass. The firm is operating at only 25% of its capacity. There is only one company manufacturing castings. Neither firm is operating profitably because of low rates of capacity utilization. Each of the major firms uses at least one subcontractor either domestic or foreign. The most frequently subcontracted operation was coating.

6. Alternate Supply Test

Is there a ready substitute for the product?

No substitute possible. Optical systems require precision optical components at a quality level commensurate with the minimum requirement. Generally, applications of target acquisition are performance limited by optical sub-system technology.

Can the system be re-engineered, in a timely manner, to work around the requirement for the product?

No known physical phenomena can be applied to re-engineer the reliance on precision optics. System level opticians do exist such as a shift to reliance on RF rather than optical signatures for detection, however, substantial system performance penalties and cost penalties probably result.

7. Government Leverage Test

Can stockpiling (either static or in the form of a revolving inventory) be used in lieu of domestic production or to buy time until a domestic source is reconstituted?

Stockpiling of material and components would be a low cost way of meeting surge requirements. Stockpiling of production equipment and raw material could assist industry in converting to defense production for mobilization. Stockpiling becomes more effective if designers are encouraged to work within the limits of the stockpiled materials or components.

Do domestic sources have the capability to develop and insert new technology, as required, into their products and Services?

Domestic sources do not have the capability to develop new optical technology since most work is done in university laboratories or in very small companies that sell into niche markets, production equipment and personnel limitations restrict these companies' ability to translate new technologies into production items. Total domestic industry research spending to develop new materials, processes or products has averaged about \$3.6 M per year. Japanese firms are currently funding more optics research in US universities than is US industry.