IDA MEMORANDUM REPORT M-110

REPORT OF THE AD HOC COMMITTEE ON THE POTENTIAL BENEFITS TO U.S. INDUSTRY FROM THE SDI/IST SCIENTIFIC PROGRAM

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PREFACE

A workshop on the potential benefits that would accrue to U.S. industry as a result of the Strategic Defense Initiative/Innovative Science and Technology Program (SDI/IST) was organized and held at the Institute for Defense Analyses (IDA) on June 17 and 18, 1985. This document, prepared under Contract MDA 903 84 C 0031, describes the program, identifies likely technological fallout, and includes copies of the visual aids used by individual speakers at the workshop.

We have attempted to provide an accurate record of the presentations and regret any errors that may have been introduced inadvertently. This Memorandum Report has been reviewed by the committee members listed on page ix.
ABSTRACT

Issues and procedures that the SDI/IST Directorate and its clients (in industry and elsewhere) may profitably use to enhance the status of U.S. industrial productivity and competitiveness in international markets are discussed. This enhancement will obtain from the utilization of the new knowledge and skills derived from SDI/IST programs and activities.
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I. INTRODUCTION

The program of the SDI/IST Directorate represents long-range research activity in support of the development of a non-nuclear, antiballistic missile defense system. It is a program of unprecedented complexity in system design as well as in the development of supporting component technologies. The major program thrusts are directed toward research on:

1. novel directed energy concepts;
2. novel sensing, discrimination, and data-processing techniques;
3. special supercomputing needs for the SDI mission;
4. innovations in burst-mode space power and power conditioning;
5. advanced materials, propellants, and structures for SDI applications.

The purpose of the program is to investigate scientific concepts that could provide new and powerful technologies for various SDI program needs.

In the past, the technological and scientific challenges represented by difficult innovations have generally not only spawned entirely new industrial developments but have also tended to accelerate the levels of sophistication, efficiency, and hence the competitive edge of U.S. industry in international markets. At the same time, fundamental research of the most challenging type has immeasurably contributed to U.S. pure and applied academic science and engineering, while playing an essential role in the education and training of new generations of scientists and engineers.
The committee believes that a properly managed Innovative Science and Technology program will provide a needed new focus, motivation, and support for advanced technological developments. Even though the primary objective of SDI is constructing an effective antiballistic missile defense system, it is expected that significant benefits from SDI/IST will also accrue to overall U.S. science and technology.
II. IDENTIFICATION OF LIKELY TECHNOLOGICAL FALLOUT FROM THE PROGRAM OF THE SDI/IST DIRECTORATE

It is easy to extrapolate to successful conclusions much of the research supported in identified programmatic areas that will necessarily be chosen in the SDI/IST program. Successful conclusion of research, in turn, implies an opportunity for wide dissemination of new technological discoveries for use by U.S. industry.

A number of important examples of past industrial advances derived from military programs will suffice for this discussion:

1. Nuclear weapons technology led to commercial power reactors, production of radioactive materials for industrial and medical applications, and advances in precision machining and fabrication technology, especially for exotic materials such as beryllium.

2. Military R&D on weapon trajectories, automatic control, flight simulation, and air defense led to the widespread use of digital computers.

3. Microwave radar development during World War II led to commercial applications of many kinds, including air traffic control; physical, chemical, and medical instrumentation (e.g., NMR); and communication systems.

4. Numerically-controlled machine tools were first developed in military R&D programs.

5. R&D in artificial intelligence was largely sustained by DARPA during the 1960s and 1970s and is now reaching the stage of application to both commercial and military needs.

6. Jet engine technology, first developed for military applications, led to the modern jet transports which
dominate the world's airways. Military R&D has been a major factor in driving up the operational turbine inlet temperature from the original 1200°F to today's value of 2500°F through a combination of advanced materials and cooling.

7. While the first integrated circuits were devised by Texas Instruments and Intel, it was military (and NASA) support of production and application technology for the Minuteman II and Apollo guidance systems that launched the microcircuit age.

8. High-strength, high-stiffness fiber composite technology for structures was a direct result of military R&D. Although the fibers themselves (e.g., boron, carbon/graphite, and Kevlar) derive from many sources, the all-important design, fabrication, quality control and operational maintenance technologies were brought to the point of practical application through military programs of the 1960s and early 1970s. High-strength, high-stiffness fiber composites are now increasingly in military aircraft (e.g., F-14, F-15, F-16, F-18, AV-8B), commercial aircraft (757, 767) as well as spacecraft, and other commercial applications such as tennis racquets and golf clubs.

The following are examples of likely contributions resulting from the current program:

- The SDI/IST program is actively pursuing new and innovative ways of producing and delivering energy. The associated development of shorter wavelength and higher power lasers has generally been encouraged and funded. The IST program in this area includes investigations of the feasibility of developing a γ-ray laser that will operate in the keV energy regime, with unprecedented intensity and high penetrability. The program could therefore provide a new and powerful technique for probing and modifying materials.
Some of the more obvious applications of γ-ray lasers include:

- γ-ray and x-ray spectroscopy with very high resolution, improved contrast, and deeper penetration for inspection of thick materials;
- holography with very short wavelength, coherent radiation for three-dimensional observations of the structures of molecules, crystals, proteins, genes, and in vivo cellular material;
- extension into the nuclear regime of precision-frequency and length (sub-nanometer) measurements based on interferometric techniques;
- imaging techniques (CAT scanners), with reduced doses and higher resolution for discrimination between molecular species;
- nonlinear effects at short wavelengths, with applications to nuclear studies;
- modifications of nuclear reactions by using highly monochromatic γ-radiation for selective removal of electrons to produce charge-density modifications at nuclear dimensions;
- determination of microscopic structure with very short exposures and high collimation at Fresnel-limited resolution;
- microreplication and fabrication of microelectronic components with high intensity, excellent collimation, and short exposure times;
- possible advances in materials science using the high intensities of ionizing radiation at very small local scales;
- fusion research that is facilitated by deep penetration with γ-rays to interrogate high-density matter.

The following are possible payoffs to the electronic power and other industries:
- improved sensors for monitoring the performance of electrical machinery;
- the development of rapid, high-capacity computers for controlling and monitoring plant operations and outputs.

- Increased knowledge of interactions between high-intensity radiation and materials may produce new manufacturing processes, new instrumentation, new surface treatments and coatings, and new super-hard materials.
- Ultra-precise sensing and measurement technology will facilitate developments of new, automated process control of material flows, distributions, and separations.
- The development of high-resolution, high-speed sensors will be utilized immediately in medical radiological imaging applications (so-called digital PACS, picture archiving and communications systems), remote sensing (oil, gas, and mineral exploration, crop and resource management), digital storage of records, and automated inspection of manufacturing processes. The development of microminiaturized sensor refrigeration devices extends all of these applications (especially remote sensing) into the infrared regime, in a cost-effective, commercially viable way.
- Major advances in optical component design and fabrication of new functional capabilities will provide options for
  - segmented, adaptive optics systems to achieve improved performance and lower cost products;
  - new energy and power management and distribution concepts and systems;
  - advanced optical computations, signal processing, and communications.
- New structural materials and design and fabrication concepts have widespread product potential, including
applications in automotive, maritime, aerospace, and biomedical industries.

- The advanced materials work includes studies on space manufacturing techniques. These techniques can lead to high-purity, very large crystals, (for computer chips, detectors, etc.) and are, at the least, expected to produce commercially viable quantities of gallium arsenides, etc.

- Development of new space-power technologies could lead to energy storage at high power densities and acceptable costs, with future use in transport vehicles;

- The developments in particle-beam generation and control and in laser technologies may be expected to lead to
  - advances in new, safe, and efficient medical diagnostics;
  - applications of advances in the accuracy of pointing and tracking to improve commercial aircraft guidance and control, as well as ground-traffic monitoring, scheduling, and control.

- Tactical forces will benefit from technologies that are developed under the SDI/IST program. Thus,
  - new technologies for tactical air defense may be obtained for air-to-air and surface-to-air applications;
  - we may anticipate designs of improved weapons, energy sources, and of pointing and tracking techniques;
  - there will be improvements in detection, identification, battlefield surveillance, and multi-sensor correlations;
  - advances in sensor hardening will, in many cases, be applicable to tactical as well as strategic systems;
- New software and artificial intelligence applications will facilitate the development of hitherto unattainable autonomous functions in robotic and automated systems for commercial and military uses.

- High-speed computing advances and advanced techniques for writing large fault-free programs will result in a new generation of mainframe computers that, in business, industry, and government will provide faster, more efficient handling of inventories, data, manufacturing, and scientific modeling.
III. ISSUES AND PROCEDURES

The SDI/IST Directorate is constrained to focus its activities and efforts on areas with demonstrable relevance to SDI program goals. Industry goals are usually oriented toward relatively short-term profit objectives, which include planned growth without undue risks. Thus, the long-term research output of the SDI/IST Directorate will generally not be immediately compatible with the relatively short-term needs of industry. However, an overlap of objectives is expected to occur over longer time scales and will become apparent when SDI/IST-derived studies produce new technological advances that are suitable for commercialization. The expected results include both improvements in existing product types and the spawning of entirely new industries, both of which would provide a long-term U.S. competitive edge in international markets. A challenge to the SDI/IST Directorate and to U.S. industry therefore exists, namely, how to optimize beneficial impacts for SDI/IST. Listed below are a number of procedural steps that may be taken to foster this:

1. A concerted effort should be made by the IST Directorate and industrial managers to ensure prompt access to information on SDI/IST program objectives and R&D results. This type of monitoring will provide prompt information flow to interested parties within participating organizations. Early applications will be facilitated by providing competent users with appropriate information on a continuing basis. Implementation of this effort requires not only a free flow
of information but also the distillation of this information in usable form. For this purpose, an IDA/IST newsletter should be created and maintained. This newsletter must be of exceptional quality: accurate, brief, and with a clear accounting of research progress and problems. Clear identification should be given of major program objectives and of the importance of discoveries for (a) SDI goals, (b) scientific progress in general, and (c) applications potential by U.S. industry.

It is important to identify research topics on which the IST Directorate requires special assistance from the industrial and scientific communities. Members of the IDA/IST-Industry Advisory Committee will be invited to contribute their reactions, comments, and suggestions regarding the status and direction of the SDI/IST research programs. Progress reports normally prepared by contractors and program managers for the SDI/IST Directorate will be useful in preparing the newsletter.

In addition to publication and distribution of a quarterly newsletter, it may be desirable to convene the IDA/IST-Industry Advisory Committee about once a year for an in-depth review of progress in the SDI/IST programs and to invite all participants to provide, on a continuing basis, their inputs in maintaining updated lists of likely technological fallouts from the programs of the SDI/IST Directorate and their interests in pursuing specific commercial applications. A central file of industry interests should be maintained to assure continuing communication of pertinent IST program progress to appropriate firms.
2. A program should be developed for industry guest workers at National Laboratories and at laboratories of contractors participating in the SDI/IST programs. The National Laboratories may well serve a special role as intermediaries with industry on special topics of SDI/IST research and development, especially those requiring nearly unique, costly facilities of the types that are often developed, maintained, and used at National Laboratories. SDI/IST-funded research at joint and interdisciplinary laboratories may also provide valuable points of contact within the industrial and university communities.

It may be useful to follow the paradigm used at the Combustion Research Facility of the Sandia Livermore National Laboratory, where guest workers from all over the world learn about new and important applications of laser diagnostics using the best available experimental facilities. The SDI/IST program will inevitably spawn new discoveries that will be sophisticated and difficult to apply. By providing access to these high-payoff and high-risk studies, industrial applications of research results may be greatly facilitated. Initiation of a cooperative program may require only an announcement by the Director of the SDI/IST Directorate to the effect that his Office will assist interested U.S. industry representatives in gaining appropriate access. Arrangements may then be worked out on an ad hoc basis by identifying one or more SDI/IST contacts for each development.

3. The SDI/IST Directorate may profitably announce the successful achievement of milestones in its research programs by convening forums designed to inform interested industry representatives of likely near-term
purchasing objectives resulting from new discoveries or advances in research.

For these open SDI/IST reports, contacts with industry may profitably include liaison with the Federal Science and Technology Committee* of the Industrial Research Institute, which has about 280 corporate members and represents about 80 percent of U.S. industrial R&D.

4. A number of SDI program goals are so complex and demanding that straightforward extrapolations of likely advances in currently known technologies will generally not suffice. There is unusual need for innovation, invention, and entirely new approaches at levels challenging the brightest and best people. These challenges are too readily dismissed as posing impossible requirements; but innovation can lead to new ways of thinking and approaching these tasks. It is especially important that these central topical issues be identified, reviewed, and periodically evaluated by national panels of experts. Examples of SDI needs that require the most demanding types of innovation and, therefore, nationwide academic and industrial participation are the following:

- computing and software,
- space-power requirements,
- midcourse (and upper terminal phase) discrimination

A dedicated national effort in these fields requires exceptional freedoms for highly competent people who are cognizant of the enormous difficulties involved and are willing to follow non-conventional approaches in order to contribute to resolution of the critical issues. Industry participation in these needs that require the most demanding types of innovation and, therefore, nationwide academic and industrial participation are the following:

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endeavors must be justified in terms of the magnitude of the potential rewards.

The committee recommends that the SDI/IST Directorate develop a special program within U.S. industry for supporting especially competent and innovative individuals who are nominated for participation in this program by their supervisors. Funding for this Innovative Industry SDI/IST program should be moderate (approximately $500,000 per year) but stable (i.e., 3 to 5 years in duration).

Because utilization by SDI of large numbers of scientific personnel with critical skills could reduce the availability of these professionals for both military and non-military uses, the committee recommends that significant and long-term commitments be made to appropriate educational institutions to ensure the training and availability of scientists to fill anticipated critical skill shortages. Less than about 5 percent of the proposals received have been accepted because of SDI/IST funding restrictions for FY 85 and 86. Many relevant high-quality proposals for research in the SDI/IST program could not be funded. This fact illustrates the present acute shortage for research funding in high-technology areas in the U.S. and shows that the presumed siphoning off of high-technology experts by SDI has not yet occurred and is not likely to occur at all in view of the ability of universities to augment trained manpower in critical disciplinary areas within short periods (approximately 4 years) compared to the SDI implementation schedule (more than 20 years).