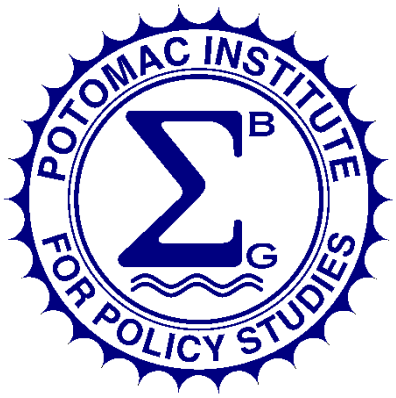
A REVIEW OF THE TECHNOLOGY REINVESTMENT PROJECT

PIPS-99-1



30 JANUARY 1999

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A POTOMAC INSTITUTE FOR POLICY STUDIES REPORT: PIPS-99-1

A REVIEW OF THE TECHNOLOGY REINVESTMENT PROJECT

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Preface

This is the final report of a study conducted by the Potomac Institute for Policy Studies (the Institute) under the sponsorship of the Defense Advanced Research Projects Agency (DARPA) and the Office of the Director of Defense Research and Engineering (ODDRE).

The Potomac Institute for Policy Studies is a not-for-profit organization dedicated to the development and support of non-partisan analysis of technology and technology policy. The Institute has conducted studies that provide insight into the impact of new technologies and processes on our society, the proper relationship between government and industry in meeting future needs, and the state of the U.S. industrial base.

We would like to thank the sponsors of this review project, particularly Dr. Lee Buchanan, then Deputy Director of DARPA, and Mr. John Jennings and Dr. Steven Wax, past Managers of the Technology Reinvestment Project (TRP) Office, for their support and insight. We would also like to thank Mr. Dan Petonito, of the ODDRE for allowing us to continue the study under the Dual Use Science and Technology Program (DUS&T). We are especially grateful for the time contributed by industry participants, DARPA program managers (PMs), and Service agents. Their generosity in sharing their valuable experience is responsible for whatever wisdom is to be found in the ensuing pages of this report. Finally, our thanks to Ms. Mary Roko, who helped immensely with our database. Views expressed are our own, however, and do not necessarily reflect the opinions of any of the contributors mentioned.

We believe this study is an honest look at the TRP, sufficient to identify winning management techniques and products that are currently benefiting the military and commercial sectors, or which soon will do so. It is important to note that this study has been on-going for some time. It is therefore inevitable that progress has occurred in many of the TRP projects beyond what is documented in this report. Furthermore, there is no question that a more intense look at the projects highlighted in this report would yield additional insight, but we feel that the report can stand on its own in offering important commentary on a remarkable program.

Executive Summary

I. Introduction

The Technology Reinvestment Project (TRP) began in FY 1992.[1] At close to $1B, it was one of the largest commercial investment programs ever undertaken by the Department of Defense (DoD).[2] This initiative was managed by the Defense Advanced Research Projects Agency (DARPA), with heavy participation by all Military Services and other government departments and agencies. Through three solicitations held in FY 1993, 1994, and 1995, the TRP sponsored 133[3] dual use technology development projects. Many are still in progress. There will be no new starts under the TRP, but some contracts will continue for another year or more, and success or failure of many projects may not be evident for over five years. The TRP also sponsored projects in two areas besides the Technology Development area studied here. They were Technology Deployment and Manufacturing Education and Training (MET). Both were funded at fairly low levels.[4]

The TRP can be viewed with respect to the areas of military need it addresses. These categories of need are: military mobility and deployment; C^4I; battlefield sensors; casualty treatment; electronics design and manufacturing; mechanical systems and materials; and weapons, survivability and other. An explanation of how each was served by TRP projects is offered in Annex C.

As the TRP ends, new programs, such as the Dual Use Science and Technology (DUS&T) Program, Commercial Operations and Support Savings Initiative (COSSI), and Commercial Technology Insertion Program (CTIP) are expanding and proliferating DoD's commercial investment strategies. Like the TRP, these programs have strengths and weaknesses, successes and failures, each of which holds important lessons for the Department.

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[1] For a more detailed discussion of TRP's history, see Chapter I and Annex B of this report.

[2] Annex A offers a list of acronyms.

[3] Two of these projects were terminated prior to beginning this study. Out of the remaining 131, 113 projects were examined and are reported on in this document. The remaining 18 projects were not included because of resource limitations, or because data was difficult to find due to the unavailability of government or industry project managers (often, the projects had shifted to new project managers, or even new companies, because of mergers or takeovers).

[4] While Technology Development projects received approximately $820M, those performed under Technology Deployment received around $230M and $60M under MET. See, *A Historical Summary of the Technology Reinvestment Project's Technology Development Program (PIPS-93-6)*, Potomac Institute for Policy Studies, 31 October 1996, (1993, 1994 Projects).

II. The TRP Review Project

The TRP has had its share of supporters and detractors, but until now there has been no formal attempt to determine how well the program has fared against an objective set of criteria. The Potomac Institute for Policy Studies (the Institute), formed a Review Team to accomplish this by identifying, measuring, and evaluating critical program characteristics. We, the Review Team, also authored this report. Specific goals of the review were to:

1. Document TRP History
2. Provide the status of each TRP Project
3. Document TRP project successes and failures
4. Provide metrics that will address requirements emerging from the Government Performance and Results Act (GPRA)[5]
5. Develop conclusions and lessons learned at both the project-level and the overall TRP program-level, which will aid in developing education and training materials for use in planning and implementing future DoD commercial investment programs, such as DUS&T and COSSI

We employed a six-step assessment process. The process was initiated by choosing the TRP objectives to be assessed and then determining how to measure success or failure in meeting those objectives (see Table ES-1). Project-level metrics were developed and a case study was written for each project (these are synopsized in Annex D). After being reviewed by the entire team, each case study was returned to the consortium leader to ensure that no company-sensitive or proprietary data was included. When all case studies were completed, successes and failures were identified and the statistics collected were aggregated to the program-level. Subsidiary questions were used to forecast the likelihood of success of immature products and to clarify metrics values. We used case studies as illustrative examples to reinforce the statistics and conclusions presented (see Chapter III of the report).

[5] The Government Performance and Results Act of 1993 (Public Law 103-62) requires the collection and reporting of metrics at all levels of government activity.

TABLE ES-1. TRP PROGRAM-LEVEL GOALS AND METRICS

ASSESSED TRP OBJECTIVES	METRICS	METRIC DESCRIPTION
1. Demonstrate the efficacy of dual use technology development for the DoD	Military/Defense Utility[6]	This metric is used in the assessment of the military or defense value of the TRP's output. Quantifiable performance and cost specifications were derived from the original proposals, military or civil market requirements, state-of-the-art performance of the technology being pursued or from other credible sources.
	Technology Transition (to the military)	Transition into a Military Service demands the commitment of Service funds to insert or continue development of the product or technology. Successful transition can occur at any level of acquisition.
	Commercial Viability	The basic metric is simple: products resulting from the project are being sold commercially.
2. Develop and demonstrate innovative management procedures	Process Metrics	This metric measures management process effectiveness. We addressed major aspects of TRP's business practices that are different from normal contracts under Federal Acquisition Regulations (FAR).

III. Some Aggregated (Program-Level) Conclusions and Lessons Learned

The TRP was an extraordinary program from many perspectives. Not only did DARPA pioneer a new mode of development called dual use, but the Agency also created innovative management tools to make it work. These tools included the use of cost share, agreements tailored to projects, consortia, flexibility on intellectual property rights (IPR) and foreign participation, and perhaps most importantly, immense empowerment of project managers (PMs), both government and industry. Most of those empowered managers performed exceedingly well, working hard to accommodate commercial interests, while maintaining military utility.[7] As a result, DARPA truly contributed a new way of doing business. The extent of that contribution is evidenced by DoD's wholesale adoption of TRP's methods and tools.

[6] The term "defense" was added to include application to non-DoD defense activities, such as some of the work done at the National Laboratories.

[7] It is important to mention that project management under the TRP was a lean operation. There were relatively few personnel in the TRP Office (even counting support contractors), and many DARPA project managers led several TRP projects in addition to other assignments. Management shortcomings identified in this report often resulted from too few hours in a project manager's day.

It is worth noting, however, that while developing approaches to successfully conduct dual use projects is vital, there are many issues upstream and downstream of this stage of the acquisition process that were not addressed in the TRP. First of all, the TRP was managed by DARPA, an agency gratefully insulated from many of the bureaucratic and organizational constraints endured by the Services. Second, like its progeny efforts, DUS&T and COSSI, TRP personnel did not really confront some of the fundamental questions that must be faced in normal acquisition. For example, all funding was delivered to the TRP to perform dual use projects – no initial decisions concerning "make or buy," or "co-develop or procure" were needed. These decisions must be confronted as a matter of course when commercial leveraging becomes normalized.

But, the aims of this study were limited to making a determination of how well the TRP performed in establishing the efficacy of dual use and in developing business practices that worked. As reflected in our two principal conclusions, we believe the answer is "extremely well." Reasons for this assertion are presented in the report. Below, we have summarized these conclusions and their rationale along with some subsidiary findings that concern each conclusion. All of this is discussed more fully in the report, with supporting statistics and examples drawn from our case studies.

A. The TRP proved that the dual use approach can bring significant benefits to the DoD. Our principal finding is that the TRP had an extraordinarily high success rate for transition to the military. Over 40 technologies or products have either been transitioned, or are being tested for transition, into a Military Service. This represents the output of 37 projects, or 33% of those examined. This is an impressive number compared to the expected 18% success rate[8] – and there are more to come. The report discusses some of these technologies and products, summarizing their progress toward military transition and commercial success (see Table 10 and Annex D). Although some of the large expected benefits from these dual use products in enhancing upgrades, logistics, and parts replacement for military equipment are mentioned in the case study synopses, we did not extensively examine them because of the difficulty of projecting this type of savings during early stages of transition. This is a major area of opportunity that should be studied closely. Unfortunately, we lacked the resources to do so under this review project. Examples of military benefits from TRP projects are listed below, followed by some subsidiary findings related to this conclusion:

- Medical technologies were an important component of the TRP. An example is the Pictorial Archiving Communications System (PACS), which demonstrated up to $2M in savings and is used in almost all DoD hospitals with digital imaging. Portable ultrasound imaging system prototypes were developed and are being tested at an Air Force Medical Center (nine units will be delivered next year). A solid state oxygen generator (SSOG), being

[8] We adopted standards of success as benchmark values for each metric evaluated. Chapter II of the report discusses how we arrived at these figures.

sold in the commercial market for home generation of oxygen for medical purposes, is also being tested by the Air Force to provide on-board aircraft breathing oxygen without the need to bleed air from the engine.

- Sensor systems include two uncooled IR technologies purchased by the Services. Over 1,000 are currently in use in such roles as security and driver's night vision devices, with a potential savings of over $500M from these and future sales. Other models are being tested for mine detection, thermal weapons sights, and terminal guidance.

  A passive millimeter wave camera and an autonomous landing guidance system are being tested on Speckled Trout testbed (the Air Force Chief of Staff's aircraft).

An electron bombarded charged coupled device camera will have twice the resolution at low light levels, ten times the sensitivity, half the package size, and a lower cost than existing image intensified night vision cameras. The technology is being applied to the Air Force's Airborne Laser and ERASER programs as well as the next generation Star Trackers for the Trident Missile.

Two gamma ray imaging systems have been sold to Nuclear Emergency Search Teams (NEST) at DoE's National Laboratories.

- Optics products were developed under two TRP projects and have delivered 200 diffractive optics eyepieces to the Army's Land Warrior program and aspheric optics for testing in Raytheon's High Resolution Ruggedized Display. The cost of lenses needed for the Javelin, UAV, M1A2 tank, and advanced laser eye protection binoculars are projected to be reduced from $100-$800 to less than $10-$80.

- Weapons and weapons support systems, including pyrotechnic devices with a Laser Igniter System (LIS), were sold to the Army for the Paladin and Crusader Artillery Systems (850 and 1100 units, respectively). According to the Army, the LIS will save millions of dollars.

  High Aspect microelectromechanical (MEMS) technology has been chosen as the baseline for a Naval Surface Weapons Center (NSWC) safety and fuzing device for its Submarine Torpedo Defense and as an upgrade for the Mark 48 torpedo.

  A micromachined gyro is a candidate for four munitions programs, including the USMC Predator missile and 5 inch Navy Extended Range Guided Munition (2,500 rounds are being produced under low rate initial production, with around 40,000 to follow).

  A Diver Alert and Tracking System is being tested by the Navy (two units delivered).

- High resolution & color thin film electro luminescence (TFEL) displays are undergoing tests for the Army's Land Warrior program. 200 Head Mounted Displays have been delivered, with 15,000 units planned. TFEL will go into low rate production for the M1 Tank (10 units are in-test).
- Structural aircraft components were fabricated with composite materials (600+ parts will be purchased for C-17 engines, with more for the Joint Strike Fighter (JSF) engine).
- Electronics technologies were also developed, to include 300 low-cost packaging prototype units, provided for use in the F-22 program; and miniature filters for wireless Networks, being tested for a classified program.
- In manufacturing, shipbuilding processes developed under the TRP are currently saving $13M per year in constructing Navy DDG-51 destroyers, and a precision laser machining project to be marketed soon has delivered a 500W laser to Sparta to be tested for unexploded ordinance destruction.
- Two TRP optoelectronic module (OEM) projects provided 6,000 Integrated optoelectronic fiber optic gyro modules for the Bradley Fighting Vehicle program over the next five years (300 sold thus far). These, and future gyro sales, have potential savings of over $40M. An analog OEM is also being applied to a DoD production program for the fiber optic transmitter of the Integrated Defensive Electronic Countermeasures system (it is estimated that 1,000+ aircraft will be equipped with this system). A number of other OEMs have been successfully employed in a demonstration of ultra-wideband shipboard electromagnetic environment monitoring on the USS Princeton.
- Software projects delivered a generic Strategic Planning Toolkit to the Navy's Bureau of Medicine (BUMED) to plan immunizations and other preventive medical care for U.S. forces deploying overseas and a medical waiver advisory tool to help place personnel who do not meet full physical-health requirements for specific positions. A capability to reuse software is also serving 400 DoD and defense contractor sites.

1. Collectively, TRP Projects were a commercial success. Out of the 113 projects reviewed, 37 projects (or 33%) are currently selling their technologies or products in the commercial market. This is well above the standard of success of 18% that we adopted. Of the remaining projects, 69 are expected to be introduced into the commercial market soon, and 12 are thought to have no prospects for success in the commercial market. Although in most cases it is too early to tell how lasting these commercial successes will be, we feel that these results are impressive and will grow as other projects begin to introduce products into the commercial sector.

2. The TRP maintained a high level of military/defense utility. The study revealed military value in 85% of the 92 projects that could be judged. Examples of products with high military utility are presented in Chapter III of the final report.

3. DARPA's tri-service role was highly regarded, but transition strategies were often lacking, or were poorly executed. 55% of the industry project managers felt that the tri-service representation offered by DARPA, as an Office of the Secretary of Defense (OSD) agency, was valuable. But, there were comments on project managers' lack of help in reaching Service customers and few transition strategies were articulated.

4. Projects with commercial goals require <u>continuing attention</u> by the government program managers. The commercial market was viewed by most consortium as more lucrative than the military market. That does not imply a disinterest in military sales. However, we felt that industry's focus on satisfying the commercial customer requires the government project manager to become far more skilled in evaluating and making performance and cost tradeoffs between the two markets.

5. Despite skepticism expressed by many critics of dual use, government <u>does</u> influence corporate investment decisions. In many cases, DARPA's backing persuaded corporate boards to sponsor a division to initiate a project, or to modify their development strategy to better accommodate the military customer. Of course part of this persuasion comes from the cost share the government contributes, but these boards were also impressed by DARPA's reputation. This ability to influence corporate decisions is usually a benefit, but it must be used carefully.

B. Business-like approaches and practices used in the TRP were well received and are crucial to program efficiency and to attract the interest of commercial industry. The second major conclusion relates to TRP's success in developing and effectively applying efficient management processes and techniques. When compared with normal DoD technology development processes, 43% of the consortium leaders specifically stated that the dual use processes used in the TRP were faster, 68% believed they were easier to perform, and 41% found them less costly to manage. In fact, 93% of the 101 consortia that responded agreed that there were benefits to the military of using the dual use approach in their project. But, interviews revealed confusion on DoD's commercial leveraging strategies and goals.

TRP failed, however, to initiate a continuous assessment process. We believe that this could have provided important insights and could have facilitated corrective actions, when needed. The lessons learned produced could have been shared with all project managers, adding emphasis to transition, for instance, and allowing fine tuning of business and management processes. Such an assessment would have enhanced the value of the TRP, yielding a larger number of product insertions into the military. Some subsidiary findings are presented below:

1. In particular, innovative agreements (Other Transactions and Cooperative Agreements), contributed to TRP's success. Of the 108 projects responding, 76% preferred TRP's innovative agreements to conventional contracting vehicles. We felt that this judgment was more negative than it would have been if implementation had not too often been degraded by the application of overly cautious contracting procedures,

particularly by agents outside of DARPA. Virtually all participants believed that, once underway, the agreements worked extremely well.

2. Rules affecting intellectual property rights (IPR) benefited both industry and government. By allowing industry to retain rights to the intellectual property generated during their project, government gained early access to some of industry's best ideas. Interviews with companies revealed that IPR was a major issue, and is likely to remain one. Resolution of this issue enabled industry to insert ideas and technologies into the project, rather than withholding them or introducing them only after the TRP project was over. Of the 108 consortia leaders responding, 97% agreed that their intellectual property rights were protected.

3. Cost Share benefited government and industry. It is axiomatic that industry's cost share reduced the cost of the development project for the government. What was not so predictable is that most of the responding companies (77%) believed that cost share benefited them.

4. Consortia were a success. 86% of those 108 companies responding appreciated the value of partnerships, but most cautioned against making consortia a requirement for selection.

5. Performance milestones worked well, but care and flexibility is needed for high-risk projects. Industry participants in technology demonstration projects sometimes felt that they were inappropriately being asked to conform to the standards of a cost-plus-fixed-fee contract.

6. Program stability was sometimes threatened. We found too many instances where delay and instability prevailed, sometimes leading to the failure of projects that would have otherwise been successful. Sometimes this was industry's fault, for example when projects were "orphaned" due to mergers or buyouts by new (and perhaps disinterested) management. Sometimes instability was a government problem.

IV. Recommendations

The lessons learned from our experience with TRP are offered with the understanding that there may well be initiatives underway in the DoD that correct some of the problems cited and take full advantage of some of the described benefits. Two major recommendations are followed by some suggestions on their implementation.

A. DoD should place a high priority on full and optimum implementation of dual use throughout the Department. TRP provides clear evidence that dual use can benefit the military. So, its proliferation and optimization should be major goals for all levels of the Department. Much is being done in the DoD to meet these goals, but implementation seems slower and less effective than it should be. Our interviews with government and industry convinced us that there were a few important steps the DoD could take to

improve the implementation of commercial leveraging in general, and dual use technology development in particular. In a previous study, the military and industry panel, led by General Al Gray, USMC (Ret.) also offered recommendations concerning implementation, many of which seem as pertinent today as when they were made.[9]

1. Commercial leveraging goals and strategies should be stated more clearly to the Department and to industry. As indicated earlier, we encountered confusion in both government and industry concerning DoD's intent and strategy for commercial leveraging. Many consortia suggested that more high-level government guidance was needed in all aspects of the TRP activity. It might be a good idea for DoD to publish a new report on the Department's commercial investment strategies.[10]

2. The DoD should initiate extensive education and training in commercial leveraging. To build upon and distribute the knowledge derived from the TRP and other commercial leveraging programs, an education and training program should be undertaken by the DoD. The program should include government and industry personnel at all levels. A critical benefit, achieved through outreach to industry, could be to encourage commercial industry to suggest government/industry partnerships in their areas, increasing the number of commercial leveraging opportunities to the DoD.

3. The DoD should create an acquisition system that maximizes commercial leveraging and transition throughout the Department. The TRP encountered many of the decisions expected in a normal acquisition process. But, some aspects of the development-through-procurement process were not experienced fully, such as the initial "make or buy" decision and acceptance procedures at all stages of the process. These additional facets can be important in enabling DoD to take full advantage of commercial leveraging and should be part of the acquisition process.

4. Working-level incentives for commercial leveraging should be introduced. The advantages of commercial leveraging are sufficiently well understood at the upper-levels of the DoD to ensure its continuation. But, we found few career or program incentives for project managers or their customers to compensate for the extra risks and effort entailed in choosing the commercial leveraging route to technology development. This is a serious misalignment that should be addressed.

B. Commercial leveraging programs should implement the management practices that worked for the TRP, while identifying and adopting new innovations. OSD is certainly taking advantage of the management techniques pioneered by DARPA under the TRP. But innovations will also emerge from DUS&T, COSSI and other new programs, because they will be managed by different people and because the Service environment

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[9] *Dual Use Research Project Report (PIPS-96-3)*, Potomac Institute for Policy Studies, 21 July 1996.

[10] This could be the "second edition" of the report: *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technologies, OSD, 1994.*

is dissimilar to DARPA's. Some management approaches that were suggested by our look at the TRP follow:

1. Employ Integrated Product Teams (IPT) in commercial leveraging. The best TRP projects resulted from industry and government people who recognized an opportunity for mutual benefit and worked out a way to take advantage of it. Recognizing and exploiting those opportunities usually demanded a broad perspective on business and military operational needs, and the innovative application of a technology to satisfy those needs. An IPT approach can provide those broad perspectives and seems appropriate for all phases of a commercial leveraging program, to include the search for better deals, making the initial acquisition decisions, conducting solicitations, negotiating and conducting development projects, and inserting the products into the military system.

2. A transition strategy should always be maintained as part of the project. The transition of TRP products were too often hampered by a lack of planning and emphasis. A transition strategy and plan should always be part of the project, to be updated when circumstances change. The customer should agree to the strategy. Goals should be identified, along with essential military characteristics that should not be traded off to meet commercial goals. The government should also stay with a project that shows potential for defense use, even after government funding is over in order to avoid "walking off the field at harvest time."

3. An assessment process should be initiated for all commercial leveraging projects. For reasons given earlier, the adoption of an assessment plan for commercial leveraging projects and programs would enhance their benefits considerably. The assessment process should be initiated early, with goals and performance and cost metrics established.

A REVIEW OF THE TECHNOLOGY REINVESTMENT PROJECT

I. Introduction and History

For reasons adequately covered elsewhere,[11] the Department of Defense (DoD)[12] has been developing and applying new strategies to leverage the commercial marketplace and the industries that serve it. Manifestations include more flexible contracting vehicles, new programs with commercial industry, and a resolve to embrace best business practices, rather than arbitrarily employing DoD procedures, specifications, and standards. The use of DoD's older strategies to employ commercial leveraging, such as the procurement of commercial-off-the-shelf (COTS) equipment and non-developmental items (NDI) is also being expanded.

A. Comments on the History of the Technology Reinvestment Project.[13] The Defense Conversion, Reinvestment, and Transition Assistance Act of 1992[14] led to the establishment of the Technology Reinvestment Project (TRP) under the management of the Defense Advanced Research Projects Agency (DARPA). The Agency was chosen for its extensive experience in developing high-risk technologies of relevance to the military in cooperation with industry. Some pertinent milestones in the life of the project are shown in Table 1.

TABLE 1. IMPORTANT TRP MILESTONES

DATE	MILESTONE
October 1992	Defense Conversion, Reinvestment, and Transition Act of 1992 becomes law
Winter 1992/93	Basic TRP strategy and federal team formed
March 1993	Fiscal Year (FY) 1993 competition announced
February 1994	Final selections from FY 1993 competition announced
April 1994	FY 1994 competition announced
October 1994	Selections from FY 1994 competition announced and FY 1995 competition announced
December 1995	Selections from FY 1995 competition announced
February 1996	Joint Dual Use Projects Office (JDUPO) is formed

[11] References include, John A. Alic, et al, *Beyond Spinoff*, HBS Press, 1992; Jacques S. Gansler, *Defense Conversion*, MIT Press, 1995; and *Dual Use Research Project Report (PIPS-96-3)*, Potomac Institute for Policy Studies, 21 July 1996.

[12] Annex A offers a list of acronyms.

[13] Additional information on TRP's history appears at Annex B of this report.

[14] See Division D, Public Law 102-484.

DARPA was required by Congress to work in concert with other government agencies on this program. Therefore, DARPA created a multi-agency council, the Defense Technology Conversion Council (DTCC), to advise, coordinate, and execute competitions. High ranking officials of the Departments of Energy (DoE), Transportation (DoT), Commerce's National Institute of Standards and Technology (DoC/NIST), the National Science Foundation (NSF), and the National Aeronautics and Space Administration (NASA) were all in attendant. In addition, a DTCC Working Group, also led by DARPA, was formed and was comprised of representatives of the federal partners and included Army, Navy, and Air Force members. The military members helped ensure that the TRP focused on military problems and benefits. The Working Group contributed both technical and managerial expertise and was co-located in the TRP office suite.

Solicitations. Three solicitations were held between 1993 and 1996, and 133 Technology Development consortia were selected (see Table 2).[15] The volume of proposals generated under the first competition nearly overwhelmed the TRP staff. To make matters worse, many of the proposers perceived the TRP as a "defense conversion" program designed solely to help defense industries affected by defense budget downsizing. As a result, the TRP received many inappropriate proposals. So, the first solicitation was very costly both in dollar value and time involved for the proposers and for the TRP staff. Because of government dollar limitations, the ratio of proposed-to-selected programs was very low, frustrating many proposers. The emphasis on military application[16] and the descriptions of the focus areas were sharpened for the next solicitation. This improved the focus of the proposals and the proportion of militarily beneficial technologies proposed. As shown in Table 2, the win rate for the Technology Development area rose significantly with each succeeding competition.

TABLE 2. TRP SOLICITATIONS

FY	Projects	Proposals Received	% Selected	Gov't Cost ($M)
1993	69	1,827	3.8%	327.6
1994	30	168	17.6%	176.4
1995	34	143	23.8%	139.3
	133	2,138	6.2%	643.3*

* Note that options later increased this total to $821M

Consortia. Congress mandated that each TRP project be organized as a consortium. All proposers were required to include two or more eligible firms and/or a non-profit research corporation. An eligible firm was defined by legislation as a company or other

[15] Two projects were terminated prior to beginning this review project. Out of the remaining 131, 113 projects were examined and reported, the remaining 18 were either too immature to project accurately or their inclusion was beyond the resources of the study.

[16] As discussed later, seven military categories were introduced to further emphasize defense relevance.

business entity that conducted a significant level of its research, development, engineering, and manufacturing activities in the United States. A firm not meeting this test could be an "eligible firm" if its majority ownership or control was by U.S. citizens. In addition, a foreign-owned firm may have been an eligible firm if its parent company was incorporated in a country whose government encourages the participation of U.S.-owned firms in research and development consortia to which that government provides funding. But, that government must also afford adequate and effective protection for the intellectual property rights of companies incorporated in the U.S. as determined by the Secretary of Commerce.[17]

Many TRP consortia regularly combined elements of the defense and commercial sectors, academia, and nonprofit organizations. For example, roughly 75 percent of the development projects selected in the first competition included both a commercial firm and a defense firm. With the right combination, teams were often able to address a broader set of problems than an organization working alone. Table 3 represents a breakout of the types of organizations that formed the TRP Consortia while Table 4 provides a demographic look at the consortia.

[17] See 10 United States Code, Section 2491(9).

TABLE 3. TYPES OF COMPANIES AS PARTICIPANTS

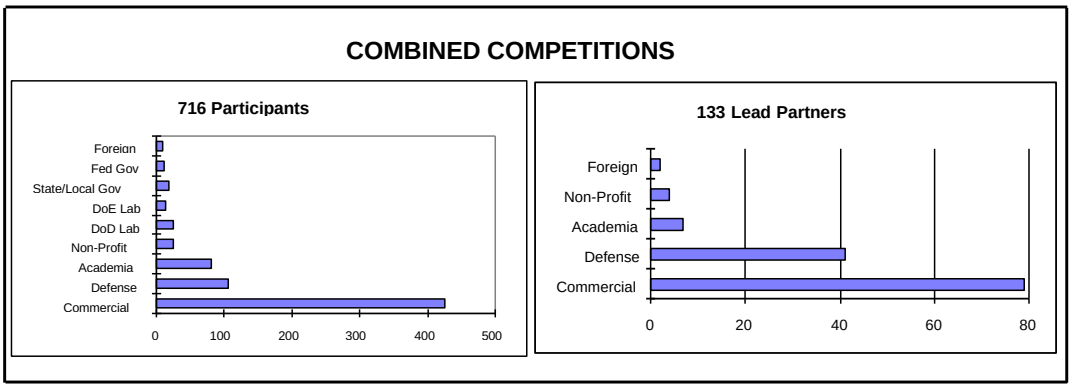


TABLE 4. NUMBER OF PARTNERS IN CONSORTIA

CONSORTIA DATA

The majority of the consortia (54%) were composed of 2 to 4 members. Another 27% had 5 to 7 members. Forty (40) of the top 100 Defense firms were represented on a consortia (many belonging to more than one consortia). Winning consortia were demographically distributed with 42 states and 4 foreign countries (Ireland, Canada, Japan, and the Netherlands) receiving funding. California, Massachusetts, and New York, in that order, led the states as far as number of proposals submitted and number of proposals selected. Not surprisingly 51% of the lead companies were from these three states.

# of Members	Competition 1	2	3	Total	Percent
2	11	1	4	16	12%
3	15	5	8	28	21%
4	15	7	6	28	21%
5	3	1	3	7	5%
6	5	8	5	18	14%
7	7	2	2	11	8%
8	4	1	2	7	5%
9	1		1	2	2%
10	2	2	1	5	4%
11	1	1		2	2%
12	1	1		2	2%
13	1		1	2	2%
16	1			1	1%
17		1		1	1%
18	1			1	1%
21	1			1	1%
24			1	1	1%

Small Business. Small businesses proved to be an excellent source of emerging technology and entrepreneurial energy, and participated quite heavily throughout all of the TRP. An average of 58 percent, for all three competitions of the TRP's Technology Development consortia had a small business on the team (see Table 5). For the second and third competitions, TRP implemented Congressional changes in its cost-sharing rules to allow Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) funds to count as non-federal dollars, making small businesses more attractive team members for TRP Development projects. Very few consortia took advantage of this cost sharing mechanism. In the second competition only four winning proposals used SBIR cost share, and in the third competition there were seven SBIR participants in six projects.

Congress continued to seek increased participation for small business. With the third competition (and the passage of the FY 1995 Defense Authorization Act) Congress

allowed small businesses, if selected, 120 days to provide acceptable documentation of available and quality cost sharing. This meant that after winning an award, they could obtain a loan (based on the assured government award) for their share of the funding. But, as shown in Table 5, there appears to have been no direct effect by this action. In fact, the percent of selected projects with at least one small business decreased considerably from the second competition. There was no data collected by the TRP office to substantiate if any of the small business participants actually took advantage of the 120 day period.

TABLE 5. SMALL BUSINESS PARTICIPATION

Development Project Only	Competition			
	1	2	3	Avg.
Percent of selected projects with at least one small business	49%	70%	56%	58%
Percent of proposed projects with at least one small business	55%	73%	70%	66%
Percent of selected participants that were small businesses	14%	24%	24%	21%
Percent of proposed participants that were small businesses	21%	29%	35%	28%

B. TRP Scope and Military Relevance. The TRP covered a broad swath of technologies. Batteries, sensors (infrared, millimeter wave radar, x-ray, and laser light detection and ranging), information technologies, low-cost electronic packaging, integrated optoelectronics, flat panel displays, telemedicine, microelectomechanical devices, and advanced composite materials are just some of the technology areas pursued under the TRP.

This breadth can also be appreciated by examining the applications of those technologies. These are listed in Table 6, along with a discussion of some thrusts pursued in each category. A further appreciation for this diversity is offered in Annex C, which discusses each category of military need in more detail and lists the projects according to the need they addressed.

TABLE 6. MILITARY NEED CATEGORIES

Military Need Categories	Applications
1. Military Mobility & Deployment	Land systems projects addressed electric and hybrid drive components, land navigation, and safety systems. Shipbuilding projects were conducted to assist U.S. shipyards and related industries to become competitive in international commercial markets to preserve shipbuilding infrastructure for defense and adopt commercial efficiencies. Aircraft technology projects included the development of fly-by-light and landing guidance systems.
2. C^4I	Projects to pursue more effective wireless communications for mobile stations, crucial for the military were coupled with intelligence and data distribution technologies, computer displays, and computer hardware and software projects.
3. Battlefield Sensors and Optics	Applications include enhanced detection in the visual, IR and RF spectra, and detection of nuclear waste and various forms of pollution. The most exciting accomplishments were in the development of uncooled IR sensor devices, but other work, in areas such as radar and cryogenic cooling components, was important.
4. Causality Treatment	The casualty care strategy was to enhance both civilian emergency and military combat casualty care through the development of biosensor devices for monitoring human physiologic parameters and for organ systems diagnosis, and information management and networking technologies for telemedicine applications.
5. Electronics Design/ Manufacturing	These projects attempted to leverage the commercial electronics market for advanced technologies and affordability typical of today's commercial industry with size, ruggedness, environmental stability and special functions that are needed for military missions. This TRP mission, was pursued in the areas of process control for electronics manufacturing, multi-chip module (MCM) technology, low cost electronic packaging, and power storage.
6. Mechanical Systems/ Materials	Some specific areas for research included the use of advanced information support for design and manufacturing, use of flexible robotic systems, integrating the description of the component/system to be manufactured with the manufacturing process, and selected areas in forming and assembly. Establishing and maintaining technological leadership in the manufacturing and use of advanced structural materials (especially composites) were also pursued to continue and strengthen the competitiveness of the U.S. aerospace industry, and to achieve performance improvements in military aircraft.
7. Weapons, Survivability & Other	Weapons needs common to the commercial and military sectors are rare, but there were three dual use weapon support systems pursued under the TRP.

C. Organization of This Report. Chapter II will explain the methodology used in conducting the study. An explanation of how metrics were derived and applied is included. Chapter III presents statistics and conclusions resulting from the study. Statistics were developed by aggregating project-level findings to the TRP program-level. These statistics are reinforced by examples from the case studies (synopsized in Annex D). As mentioned previously, this roll-up will be accomplished in terms acceptable to the Government Performance Results Act (GPRA).[18] Chapter IV offers some recommendations that flow naturally from our conclusions.

[18] The Government Performance and Results Act of 1993 (Public Law 103-62) requires the collection and reporting of metrics at all levels of government activity.

II. The TRP Review Project

A. TRP Review Project Objectives. In order to develop innovative new management processes that provide solutions to today's problems, DoD has often sponsored "Pathfinder Programs." These programs are generally composed of a number of individual projects or activities which embody the new management process, allowing it to be evaluated and modified until it either proves or disproves the efficacy of the proposed concepts.[19] The goal of evaluating and perfecting the new concept is generally accepted as transcendent over the success of individual constituent projects or activities. Examples of these Pathfinder Programs include the TRP and DUS&T (dual use science and technology co-development), COSSI (commercial product insertion into military systems), MARITECH (addressing a commercial market to sustain the Navy shipbuilding industrial base), and Advanced Concept Technology Demonstrations ([ACTDs] validation of candidate advanced technology concepts through troop testing).

Unfortunately, attention nearly always focuses immediately and exclusively on the projects themselves, neglecting any assessment of whether the larger principals were vindicated by the program as a whole. This happens for a number of reasons. First, the span of control for the program is often large, demanding the distribution of responsibility for subsidiary projects among many individuals, and often agencies or departments. Second, it is natural to assume that the project managers (government and certainly industry) will concentrate on their area of responsibility -- their project. Further, although the program-level managers begin the process with the larger goal in mind, they often become distracted by an aggregation of problems at the project-level, and bureaucratic and political demands that quickly outstrip their (generally lean) resources. Finally, judgments associated with how well the new concept works must be made over a period of years, since final conclusions can only be reached after the individual projects have been completed and their outputs either accepted or rejected by the targeted customers.

As a pathfinder program, the TRP has had its share of advocates and detractors, but until now there has been no systematic attempt to determine how well the program has fared against an objective set of criteria. In the TRP Review Project, the Potomac Institute for Policy Studies (the Institute), formed a Review Team to accomplish this by identifying, measuring, and evaluating critical program characteristics. We, the Review Team, also authored this report. Beginning with four areas of assessment (military/defense utility, transition to a Military Service or defense establishment, commercial success, and management processes), we developed questions and metric criteria to judge the worth of the TRP in benefiting the military and in addressing the commercial sector.

In order to accomplish this we have tried to deliver an honest evaluation of the output of the TRP. Where a project has not reached its conclusion, we often had to predict likely outcomes. We viewed this study as an opportunity to develop conclusions and lessons

[19] Throughout this report, a "project" will be defined as one of the 131 individual projects being conducted under the TRP.

learned that can be valuable in implementing future DoD commercial investment strategies.

These objectives demand examining projects at each stage of progress. We chose to conduct the review in a case study format. Findings from these case studies are then aggregated at the TRP program-level. Specific goals of the Review Project were to:

1. **Document TRP History.** Provide a brief history of the TRP to form a backdrop for the study.
2. **Report status of each TRP Project.** This status is expressed in terms of military utility, transition to a Military Service or defense establishment, commercial success, and effectiveness of management processes.
3. **Document TRP Project successes and failures.** Stories of success and failure are documented in order to illustrate findings.
4. **Provide assessment metrics consistent with the GPRA.** Because the TRP Office did not establish and evaluate metrics from its inception, it has sometimes been difficult to identify quantifiable criteria for success. The Review Team formulated metrics through revisiting the original proposals, discussing goals with the industry and government project managers, and applying our own judgments. Sometimes all of these avenues dead-ended into a subjective criteria, but most often we were able to quantify success.
5. **Develop conclusions and lessons learned at individual project- level and overall TRP program-level, which can aid in developing education and training materials for new DoD commercial investment programs.** These lessons reflect observations on the effectiveness of technology or product areas, government and industry management, insertion strategies, and Military Service involvement and coordination. The management process was examined to develop ideas on how techniques and strategies can improve and guide the transition of program management processes into the Services.

It is important to address the scope of this study. This report contains case studies of over 100 diverse and complex projects. Given the usual constraints of time and money, we opted to provide a somewhat summary examination of nearly all of the TRP projects, rather than to perform an in-depth analysis of only a few. We believe the decision was vindicated in that accurate information was collected, which proved useful to our analyses. This was due principally to the willingness of government and industry project managers to spend time with us, helping us to understand the salient points of their projects. Our decision to initiate the review project by developing a process and a set of fundamentally essential metrics and questions enabled a better focus on those salient points.

It is undeniable, however, that rigid validation of information was difficult under these circumstances. We accepted data that we felt to be reasonable from project managers,

often (but not always) confirming it through discussions with both industry and government. Our final acceptance of a case study involved discussions among Review Team members, where we imposed our judgments on outcomes, and more significantly, on projected outcomes. But, this study did ask questions that, for many projects, had not been asked previously. This led to some necessary hindsight, such as defining what would have been the critical performance and cost specifications if they had been formulated at the beginning of a project.

B. TRP Review Project Approach and Schedule. In order to maintain consistency, all information was gathered and analyzed by the members of the Review Team.[20] Sources of information included government program managers, representatives of participating companies, and military users. A six-step assessment process was developed for this project, and was later employed in the MARITECH Review Project.[21] These steps, and their application to the TRP, are explained below.

1. Identify the principal goals of program: Two TRP goals were examined in this study:

a. *Demonstrate efficacy of dual use technology development for the DoD*

b. *Develop and demonstrate innovative management procedures*

2. Develop program-level metrics for each principal goal: We developed program-level metrics to evaluate the two TRP goals evaluated. Four program-level metrics are discussed below.

a. *Military/Defense Utility:*[22] This metric reflects the military utility of the program's collective output. It poses the question, "What percentage of the output of this program is useful to the military?" As will be discussed later, we tried to establish performance or cost standards to assess the military value of each emerging product. The standard for success for this metric was that at least 80% of the projects should be useful to the military.

b. *Technology Transition (to the military):* This is the major measure of success of the program. The question asked is, "What percentage of the output of the TRP has been, or is likely to be, inserted into the Military Services?" We determined that the criterion for a successful transition into a Military Service should be the commitment of Service funds to insert or continue development of the program's products or technologies. An 18% standard for success seemed reasonable. Because of the absence of data on the rate of success for military

[20] Review Team members are listed on the report cover.

[21] See, *MARITECH Program Impacts on Global Competitiveness of the U.S. Shipbuilding Industry and Navy Ship Construction (PIPS-98-4),* Potomac Institute For Policy Studies, 1 July 1998.

[22] The term "defense" was added to include application to non-DoD defense activities, such as those of the National Laboratories (e.g., NEST Teams).

transition, we based this standard of success on available figures for successful commercial market entry (discussed below).

c. *Commercial Viability:* Commercial success is necessary for the DoD to realize the efficiencies and economies to be gained through the commercial marketplace. The basic question posed is simple, "What percentage of the products resulting from the TRP are being sold commercially?" The standard for success was chosen from commercial expectations derived from several communities, including patents, commercial projects, and venture capitalism. A recent study by Stevens and Burley[23] found that it took 3,000 unwritten ideas, and four to nine development projects (depending on size) to create a successful market entry. Their results are summarized in Figure 1. We agreed that the average TRP project fell between the definition of a significant and a major development and so, we adopted a success standard of 18%. This standard of success seems high, according to a study by H.P. Hertzfeld, who reported that, during the period 1959 to 1979, the commercialization rate of the 30,000 patents held by the U.S. Federal Government as a whole was about 5%.[24]

More insight into the difficulties of commercializing technologies is provided by the experience of the Danish Product Idea (DPI), a company that tried to find and market relevant research ideas at institutions of higher learning. From 1980 to 1990, they examined 5,000 ideas. Of these:

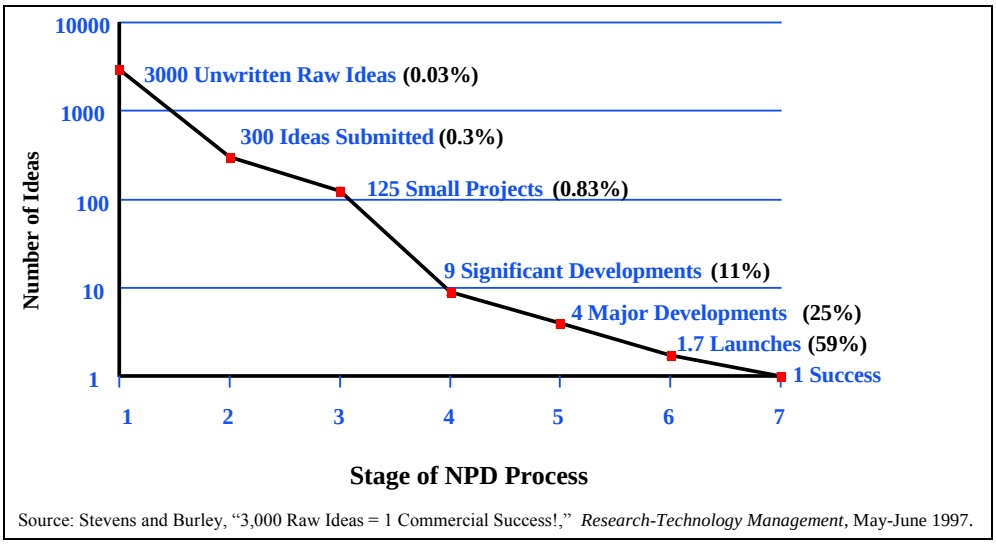
- 350 (7%) were pursued,
- 94 (1.9%) were licensed by companies,
- 30 (.06%) were produced, and
- 15 (.03%) were still in production in 1991.[25]

[23] Greg A. Stevens and James Burley, "3,000 Raw Ideas = 1 Commercial Success!" Research-Technology Management, May-June 1997.

[24] H.P. Hertzfeld, *Measuring the Economic Impact of Federal Research and Development in Civilian Space Activities,* National Academy of Sciences Workshop on the Federal role in R&D, 22 November 1985.

[25] Povl A. Hansen, "Publicly Produced Knowledge for Business: When is it Effective?," *Technovation* 15, Nr.6, 1985: pp. 387-397.

FIGURE 1. EXPECTED SUCCESSES OF VARIOUS STAGES OF COMMERCIAL EFFORTS



Source: Stevens and Burley, "3,000 Raw Ideas = 1 Commercial Success!," *Research-Technology Management*, May-June 1997.

d. *Process Metrics* measured the overall effectiveness of the TRP's management processes. We attempted to cover all major aspects of the TRP way of doing business that are different from normal contracts under the Federal Acquisition Regulation (FAR). The effects of these unique procedures and rules have been examined for each project. We adopted a positive response from at least 50% of the participants as the standard for success.

3. Design an assessment structure and process: This was a retrospective review. TRP was essentially finished and feedback to directly improve project efforts was not possible. The assessment process was designed with the following features:

a) an independent review team,

b) case studies,

c) project-level data and findings aggregated to the program-level, and

d) conclusions and lessons learned.

4. Develop project-level metrics and format case studies:

Project-level metrics were derived to measure the performance of each project in addressing the four program-level metrics. Project-level metrics were formulated with the help of DARPA program managers, industry, and Service Contracting Officer's Technical Representatives (COTR). Subsidiary questions were posed to clarify metrics values, and to provide rationale for projected outcomes. Both metrics and questions are provided in Chapter III of the report.

a) *Military/Defense Utility:* This metric is used in the assessment of the military or defense value of products, processes, or technologies resulting from each project. We considered military utility to be an "entry-level requirement" in that it was the principal proposal acceptance criteria in the TRP. We attempted to establish quantifiable performance and cost specifications that are credible indicators of how well the output of the project satisfied a military need. To that end, "specifications" were derived from the original proposal, from military requirements, descriptions of state-of-the-art of the technology being pursued, or from other credible sources. Table 7 illustrates our approach, using the Uncooled Infrared Project as an example. If the utility index was greater than one, the product was considered to be potentially useful to the military. It is important not to confuse military utility with transition, since it is quite possible to end with a product that would be useful to the military, but which the military fails to buy. On the other hand, a military sale was assumed to imply utility.

TABLE 7. A SAMPLE MILITARY UTILITY MATRIX (UNCOOLED IR)

Military Utility Performance Measures

Cost, Availability, & Performace Specifications	Needed Value	Accomplished	Utility Index
Unit Cost	$10,000	$8,000	1.25
Sensitivity	0.1 degree @ F1 Aperture	0.055 degree @ F1 Aperture	1.8
Weight	1,000 grams	740 grams	1.35
Volume	11 X 10 X 13 cm	11 X 10 X 13 cm**	1.0

a) **Yes** (Composite Utility Index equal to or greater than 1)

b) No (Composite Utility Index less than 1)

Explanation: Unit Cost: The Low Cost Uncooled Sensor Project (LOCUSP) yielded a prototype that cost $30,000. It was determined that an acceptable cost for proliferation among Army troops would be between $1,000 and $10,000, and indeed the market seems to be responding to this price range. Major improvements in producibility and innovative new processes reduced the two most costly thermal imaging components (the IR imager and detector) to new levels of affordability. The key accomplishments included a 10X cost reduction for detectors, a 65% cost reduction for IR imagers, and a 3X overall system cost reduction. The commercial automotive driver's night vision unit price target is $500 -- not yet achieved.

Resolution: To serve as a night driving aid, the sensor must provide road vision. To serve as a manportable night vision device and rifle sight (called Nightsight™), resolution should be sufficient to view a man at approximately one mile, requiring a resolution of 0.1 degree sensitivity at the F1 aperture -- the most onerous requirement. It was chosen as the performance metric. If the device is to be incorporated as a missile seeker, it must provide the 0.1 degree sensitivity at the F2 aperture. The $8,000 sensor has a .2 Degree sensitivity at the F2 aperture. The .055 Degree sensitivity comes at a higher cost (see case study synopsis in Annex D).

b. *Technology Transition (to the military):* Successful transition can occur at any level of acquisition, from equipping a fielded system to insertion in the technology base of a Service laboratory. For less mature projects, we used answers to the subsidiary questions to judge the likelihood of transition. The Portable Shipbuilding Robotics Project contributed to military efforts in multiple stages of development (see Table 8 below):

TABLE 8. AN EXAMPLE OF TECHNOLOGY TRANSFER (PORTABLE SHIPBUILDING ROBOTICS)

TRANSITION CATEGORY	NUMBER OF UNITS PURCHASED/$AMOUNT
[X] **a. Fielded System**	3 Cutting units/$2M Total cost
[X] **b. Developmental System**	1 Welding unit
[ ] **c. Military Service Technology Development**	
[ ] **d. Potential for Insertion**	
[ ] **e. No Prospects**	

The consortium leader, Cybo Robots, Inc., notes that transition to the Navy was successful. Cybo spent $350K of their funds to support field trials to demonstrate the system in a Navy production shipyard. They also spent more than $4M of their funds to date to commercialize the technology, resulting in $2M in delivered shipyard orders and $1.2M in commercial orders. Cybo plans to continue investing in commercialization. The technology is currently under evaluation for upgrading production capabilities for rocket and space shuttle engines and military vehicles (see case study synopsis in Annex D).

c. *Commercial Viability:* The basic criterion is simple: products resulting from the project are being sold commercially. Again, for immature projects, subsidiary questions allow judgments as to the potential for commercial success. Table 9, below offers an example of how we rated commercial status for the Consortium - The Path to a Globally Competitive MCM Industry in the U.S.

TABLE 9. AN EXAMPLE OF COMMERCIAL VIABILITY (CONSORTIUM - THE PATH TO A GLOBALLY COMPETITIVE MCM INDUSTRY IN THE U.S.)

COMMERCIAL STATUS	NUMBER OF UNITS SOLD/$AMOUNT
[X] **a. Being Sold Commercially**	Sputtering System/$3.1M and high speed bonder/$0.2M
[X] **b. Pending Sales**	Sputtering Systems: 1 per quarter, 3 bonders on order
[ ] **c. No Prospects**	

The MCM consortium has subcontracted for a number of manufacturing tools that are needed for the large format MCMs. Intervac has already sold one of the large format MCM systems and two even larger systems, capable of uniform sputtering over 1 m by 1.3 m. These are based on the design developed under the TRP project. Other orders are pending. Palomar has produced pre-

production high-speed, large-area gold wire bonders. A number of other developments will become commercial products (see case study synopsis in Annex D).

d. *Process Metrics:* This metric was measured directly from the opinions of participants on how well the management rules and processes worked. The overarching judgment was called for and each respondent was asked if the TRP management process resulted in a faster, easier to perform, or less costly project.

Case studies are divided into narrative and metrics sections. The narrative documents background, objective, military relevance, and commercial motivation. This section also includes a synopsis to summarize outcomes and success or failure of the project. The metrics section consists of values for each metric and answers to the subsidiary questions. The case study is written with inputs from available documentation, interviews with government and industry participants, and other pertinent data.

All case study reports, answers to subsidiary questions, metrics ratings, and success stories were developed by the researcher(s) responsible for the project being examined. Input from DARPA PM's, Service representatives, and others were sought to provide clarification and validation. Meetings of the Review Team were held regularly to further develop, review, and approve all documentation. After completion of all interviews and analyses, each case study was sent to the industry point of contact for review and comment. This was to ensure that the interview team captured the important points, that statements were recorded accurately, and that no proprietary or company sensitive data was inadvertently published.

5. Aggregate project assessments to the program-level. Project-level metrics and findings were aggregated to form program-level statistics. These statistics and other data from the case studies were used to form conclusions and lessons learned.

6. Report progress, lessons learned and recommendations. These are reported in Chapters III and IV.

III. Conclusions and Lessons Learned

The aims of this study were to determine how well the TRP performed in establishing the efficacy of dual use and in developing business practices that worked. As reflected in our two major findings, we believe the answer to both is "extremely well." It is the purpose of the following to articulate and substantiate the reasons for this assertion. To that end, this chapter presents our major conclusions, along with several subsidiary findings (presented under the associated major conclusions) supported by statistics derived from the 113 projects examined during this study.

In addition, examples are used throughout this chapter to illustrate our conclusions and findings. These examples are not meant to be comprehensive, and some were chosen to highlight views contrary to our findings. We believe that these perspectives, taken principally from interviews with the government project managers and the participating companies provide valuable insights. *Two cautionary notes are appropriate. First, although we sometimes use the names of corporations or government agencies to indicate sources of comment, the actual sources are individuals within those corporations and agencies and comments cited do not necessarily represent a corporate or government position. Second, we have paraphrased most of the comments for reasons of style, format, and conciseness. As a result, most are not direct quotes. Hopefully, we retained both the spirit and facts so kindly furnished.* Additional details are to be found in the case study synopses presented in Annex D.

A. Technology Transition

Major Finding: ***The TRP proved that the dual use approach can bring significant benefits to the DoD.*** Our principal finding is that the TRP had an extraordinarily high success rate for transition to the military -- much greater than the chosen standard of success. This yielded an impressive number of products that either have been, or are being inserted, into the Military Services – and there are more to come. Table 10 describes over 40 technologies or products that have either been transitioned, or are being tested for transition, into a Military Service. This represents the output of 37 projects, or 33% of those examined.[26] It is expected that 14 products or technologies will be inserted into fielded systems, 24 into developmental systems, and 7 will receive funding under Service S&T programs.[27] These projects are expected to result in cost savings to DoD of more than $900M during the next ten years.[28] Although some of the large expected benefits from these dual use products in enhancing upgrades, logistics, and parts replacement for military equipment are mentioned in the case study synopses, we did not extensively examine them because of the difficulty of projecting this type of savings during early stage of transition.[29] These are major contributions to defense acquisition that should be studied closely. Unfortunately, we lacked the resources to do so under this review project.

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[26] This should be compared to our chosen success standard of 18%.

[27] Note that a project can furnish products for several fielded and developmental systems.

[28] The most difficult metric value to determine was the defense cost savings represented by a product. We were conservative on cost savings claims (probably too much so). The Review Team feels that a close examination of the projects identified as transitioning products to the Services would result in cost savings much higher than the $900M cited, but such an examination was impossible given the time and resource constraints of the TRP Review Project.

[29] For example, the commercial sector has reduced the cost of the $34,000 DoD-developed GPS to about $800 over the past five or so years, with instant delivery.

The TRP sometimes sponsored competitive approaches to meet identical needs. This strategy, illustrated by projects to develop uncooled IR, digital x-ray, and ultrasound imaging devices, often paid off. There were 67 projects with expected insertions, meaning that, while insertion looked possible, none had occurred. On the other hand, we felt that 10 projects had little chance of transitioning technologies or products generally because the product or technology did not meet expectations. We assumed failure to transition when both industry and government had ceased funding the project, short of successful insertion of products into the military.

For those projects that were too immature to transition, we asked several questions designed to determine the likelihood of transition. From these we found that 46% of the products had been tested by or for the military and were judged to meet the goals of those tests. Fifty percent (50%)of the technologies or products received an endorsement from the Military Service, either formally or informally.[30] Finally, 34% of the projects had transition funds budgeted by a Service, incorporated in Service out-year plans, or were part of an ACTD.

[30] Successful transition was considered an endorsement. Note that we did not demand a formal requirements document.

TABLE 10. TRP TECHNOLOGY AND PRODUCT TRANSITIONS

TRP PRODUCT	BENEFIT TO SERVICE	COMMERCIAL MARKET
Shipbuilding Processes (3353)[31]	Processes developed are currently saving $13M per year in constructing Navy DDG-51 Destroyers.	Failed to address the commercial market.
Barium Strontium Titanate Uncooled IR Sensors (5093) and *Microbolometer Uncooled IR Sensors (5054)*	Services have purchased over 1,000 of these sensors for use in security and driver's night vision devices. Services purchased ten mine detection units and two thermal weapons sights. Fielding depends on acceptance by the Army for its Omnibus Weapon's Sight procurement. Navy is developing a glide bomb using this technology for terminal guidance.	Police/law enforcement, USMC, and heat measurement applications have resulted in sales of over 900 units. 150 AGEMA Thermovision 570 systems are on contract, with 50 more expected next year.
Pyrotechnic Devices and Laser Igniter (1197)	Product improvement for Army artillery systems - Paladin (850 units) and Crusader (1,100 units) (over 10,000 LIS ignited rounds have been fired).	Sales of 600 units per month for rescue equipment.
Integrated Opto-Electronic Modules (2681)	6000 fiber optic gyros will be sold to the Bradley Fighting Vehicle program over the next five years (300 sold thus far).	Commercial use is to address the large Fiber-to-the-home (FTTH) market - $6M contract with Japan.
Analog Optoelectronic Module (3541)	Module has been inserted into the Integrated Defensive Electronic Countermeasures system.	Sold 1,000 units at $1,000 each.
High Aspect MEMS Technology (3798)	NSWC is baselining a HIMEMS Safety and Fuzing device for its Submarine Torpedo Defense (SMTD) and as an upgrade for the Mark 48 torpedo.	PENDING - For pulmonary and respiratory function flow sensors, magnetic disc drive, gyroscopes.
Passive Millimeter Wave Camera (1167)	Air Force testing on the Speckled Trout testbed (AF Chief of Staff's aircraft) is underway.	PENDING - Marketing for oil spill detection and aircraft landing systems.
Autonomous Landing Guidance System (3462)	Also being tested on Speckled Trout at this time.	PENDING - FAA certification being sought.
Advanced Pictorial Archiving Communications System (2576)	Demonstrated up to $2M savings in hospitals with 250 radiological exams per day. Being used in almost all DoD hospitals with digital imaging capability.	Ten units sold commercially (e.g., Hammersmith Hospital, Mayo Clinic).

[31] Tracking numbers in parenthesis are used to locate projects in the Institute's database.

TRP PRODUCT	BENEFIT TO SERVICE	COMMERCIAL MARKET
Portable Ultrasound imaging System (12026)	Three units delivered to USAF Medical Center for testing (six more to be delivered next year).	Commercial sales to begin in 3rd quarter 1999.
Advanced Composites for Bridge Infrastructure Renewal (1230)	Planned to replace Army Vickers bridge. Demonstrated one-track portable bridge that met Army cost, weight, and performance goals. Next a two-track bridge will be built and tested. The benefit is that one tank will be able to carry two bridges instead of one.	Demonstrated to be effective for the repair/retrofit of concrete bridge decks. Composite bridge replacement deck system (1/10th weight and same load capacity).
Composite Materials for Aircraft (1428)	The Advanced Composites TRP project furnished fan and doors for the C-17, and fabricated and tested prototype composite structures with 30% cost and 40% weight reductions. It has been transitioned to the Joint Strike Fighter and DUAP programs.	PENDING
LEGOS: Object-based Software Components for Mission-Critical Systems (5088)	This capability, to reuse software, is in use at 400 sites, including the Air Force Phillips Laboratories, the Naval Sea Command, the Naval Ordinance for an ordinance management system, Rome Laboratories in their Imaging Laboratory, and DoD systems houses such as TRW and Lockheed. TRW uses it in their Nuclear Readiness Management System.	Licensing fee revenues of $5.5M attributable to the TRP.
Low-Cost Packaging (5114)	300 Prototype units have been provided for use on the F-22 program. There is also interest by other military systems, both for RF and digital applications.	250,000 preamplifiers and 4,000 38GHz Point-to-Point Data links have been sold with this technology. Next-generation digital phone sales began in CY 1997. Seed money received from telecommunications companies in the U.S., Europe and Asia.
Software for "Virtual Enterprises" (2055)	These software protocols enable globally competitive "Virtual Enterprises" used on DoD programs by Electric Boat Corp. and Lockheed Martin to save $20.5M per ship and $700K per F-22 respectively. Projected life cycle costs on the Joint Strike Fighter program would amount to $3B.	Five companies have developed over 30 specific SW programs that support "Virtual Enterprises."

TRP PRODUCT	BENEFIT TO SERVICE	COMMERCIAL MARKET
East/West Consortium: Next Generation Authoring Tools & Instructional Applications (2125)	A direct spin-off is DoD's Advanced Distributed Learning program. DoD schools, from K-12 to specialized institutions, adopted tools and services from this project. Another is the WorldBoard concept, which combines GPS-equipped wearable computers for location-cued data with wireless Internet, automated content filters, augmented-reality displays and touch interfaces.	This effort allows all-mobile interactivity. WorldBoard derives from the EOE [Educational Object Economy] Foundation, an Apple Computer startup that promotes software "objects" (building blocks) for CAI authoring.
Hydrostatic Bearings (2739)	These non-oil lubrication bearings are now part of two programs under the Air Force's Integrated High Performance Rocket Propulsion Technology Program, the Integrated Powerhead Demonstration and the Upper-Stage Demonstration.	PENDING - Will address the space launcher community.
Gamma Ray Imaging System (3079)	Two units sold to NEST units at National Labs.	PENDING - British Nuclear Fuels, Ltd. in negotiation to buy six units.
Diver Alert and Tracking System (DATS) (14016)	Two units have been purchased for testing by the Navy. The product will produce Differential GPS-like navigation accuracy for divers in litoral areas. Tentative Operational Requirements exist for technologies that allow mapping of undersea mine fields by Navy divers.	DATS will be added to the commercial dive computer. Market surveys indicate that 14,000 diver units and 2,000 boat units will be sold by the year 2000. First commercial sale is being negotiated to provide security in the Sydney, Australia harbor during the 2000 Olympics.
Solid State Oxygen Generator (SSOG) (1408)	Brooks Air Force Base is applying SSOG to generate on-board aircraft breathing oxygen (prototype generators have been provided for in-house testing). New capability: Military aircraft use does not demand that it bleed air from the engine. Technology also used to demonstrate a fuel cell for DARPA (ran for 100 hours at 600 degrees Centigrade in unreformed methane without sooting).	Licensed to NetMED, a medical supply company, for application to the home health care market (a $1B per year market), and is currently in the pre-manufacturing phase.

TRP PRODUCT	BENEFIT TO SERVICE	COMMERCIAL MARKET
Precision Laser Machining (1493)	Project is 18 months still underway, but has already been productized for sale to military and civilian industry. The DP-11 Precision Laser Machine, with 500W of average power, is being incorporated by SPARTA into a system for the destruction of unexploded ordinance and to Cummins Engine Company for use in evaluating its potential in drilling and machining applications.	Possible initial application in automotive industry to reduce auto manufacturing costs by $185 per car through use of laser welding. Industry experts project that this translates to an increase in market share and increased annual sales revenues of $1.7B.
Model based Control and Diagnostics software (10018)	Joint Strike Fighter Program Office is baselining its diagnostics on this software.	Introduction set for Ford's Taurus (Model year 2000 or 2001).
High Resolution & Color TFEL Displays (5040)	200 Head Mounted Displays sold for "Land Warrior" - 15,00 units planned. TFEL will go into low rate production for the M1 Tank (10 sold for testing).	PENDING - Commercial testing underway.
E-Smart System for In-Situ Detection of Environmental Contaminants (5047)	A prototype 23-node E-SMART sensor network was successfully tested at Tinker AFB for monitoring ground water contamination. USAF has appropriated $4 million for a follow-on program for more testing. Remediation is the current E-SMART market, but Photonic Sensor Systems, Inc. is studying biological warfare agent-sensing variants of the team's E-SMART sensors for DoD, and Biode, Inc. is funded by DoD for variants addressing chemical warfare agents. Both classes of sensors will be prototyped in less than one year.	E-SMART interested a Japanese company that wants to sell E-SMART sensors. This inquiry prompted an E-SMARTS trade-show display in Tokyo.
Surgical Simulation for Limb Trauma Management (1973)	An Alpha version of the Limb Trauma Simulator (LTS) was delivered to the Special Operations Medical Training Center (SOMTC) to integrate LTS into their curriculum. Recently, MusculoGraphics installed a beta version of the LTS available at SOMTC and two at the Uniformed Services University of Health Sciences. Both are being used, but were not purchased by DoD.	A commercial sale of the LTS was made to Hong Kong Polytechnic University. More prospects are being considered.

TRP PRODUCT	BENEFIT TO SERVICE	COMMERCIAL MARKET
Consortium - The Path to a Globally Competitive MCM Industry in the U.S., The (3087)	Boeing plans to use large format MCM technology for the distributed power supply and the prognostic health monitoring (PHM) subsystems for the joint strike fighter (JSF). For the PHM electronics and sensors will be integrated into one MCM. Raytheon plans to use this technology for the F-22 radar.	PENDING -- If this project reduces MCM costs sufficiently, the U.S. market is accepted to be in the $30-$40 billion dollar range by the year 2000.
Electron Bombarded CCD Camera (EBCCD) (14018)	The EBCCD technology is being applied to the Air Force Air Borne Laser program. Intevac is under contract to Lockheed Martin to supply seven cameras using this technology for the aircraft. The EBCCD technology is also being applied to the Air Force ERASER program. The EBCCD technology is also being examined for use in next generation Star Trackers for the Trident Missile.	Intevac plans to offer EBCCD cameras commercially in 1999. A product announcement has been made. They expect to produce 50 cameras in 1999.
Cryo-Electronics for Microwave Systems (17004)	High-temperature superconducting filters from this project are the subject of a Navy ACTD for high frequency surface-wave radar (from Lockheed Sanders) that can propagate over the horizon and follow the earth's curvature, providing detection of low-flying anti-ship cruise missiles at ranges double those available from conventional radars.	STI's HTS filters are being sold commercially for cellular-phone base stations. 100 filters sold $25,000. U.S. market has 60,000 base stations -- tripling over next five years. The team plans to target the U.S. wireless market first, followed by the global market. The filter is in low-rate production at one per day, with three per day expected by mid-1999.
Object Technology for Rapid Software Development and Delivery (5154)	The project produced two products for the Navy's BUMED generic Strategic Planning Toolkit: a tool to plan immunizations and other preventive medical care for U.S. forces deploying overseas, and a medical waiver advisory tool to help USN place personnel who do not meet full physical-health requirements for specific positions.	In commercial markets, Template and team members IBM and ISX have made commercial sales of the project's tools.
Electronically Controlled Variable Displacement Vane Pump (VDVP) (1024)	The Propulsion Directorate of the Air Force Research Laboratory has begun a follow-on program to develop the VDVP.	Originally expected to sell commercially, the VDVP saw a market develop by 1997, it is now expected that volume sales of this pump will not occur until 2001.

TRP PRODUCT	BENEFIT TO SERVICE	COMMERCIAL MARKET
Computer-Aided Earth Moving (CAEM) With DP-GPS (3353)	The Army would field CAEM as a COTS item. CAEM can be purchased as an integrated end-to-end system, complete with autonomous blade control, fitted to new vehicles from Caterpillar. Two other vendors (Spectra Laser-Plane and Leica) sell CAEM components that can be fitted on U.S. or foreign-OEM earthmovers.	See "Benefit to Service."
Aspheric Optics (15003)	PENDING - Supplied parts for testing in Raytheon's High Resolution Ruggedized Display.	PENDING
Miniature filters for Wireless Networks (13003)	PENDING - Being tested for application to a classified program.	PENDING
SONET OC-192 and ATM Self-Healing Ring (2595)	Leased from commercial sector by DoD (NSA and DISA) for high traffic route data flow transmission.	PENDING
Diffractive Optics (15002)	200 eyepieces delivered to "Land Warrior" Program. Scatter codes developed in this project have been incorporated into the FLIR system being developed for the A2GF helicopter and are under evaluation for the LRAS3 System.	The company now receives 25% of its commercial sales from these diffractive optics.
Aspheric Optics (15003)	PENDING - Supplied parts for testing in Raytheon's High Resolution Ruggedized Display.	PENDING

Subsidiary conclusions include:

1. Collectively, TRP projects were a commercial success. Many products from TRP projects are currently being sold commercially (see Table 10 for examples). Out of the 113 projects reviewed 37 technologies or products are reportedly marketed in the civilian sector. This is 33% of the projects studied (much better than the 18% standard of success chosen). Further, 69 projects have technologies or products that will be introduced into the commercial market soon. But, ten projects are thought to have no prospects for success in the commercial market. Although in most cases it is too early to tell how lasting these commercial successes will be, we feel that these results are impressive and will grow as other projects begin to introduce products into the commercial sector.

Comparing success in both military and commercial markets: 16 projects appear to be successful in placing technologies or products in both. So, 43% of the projects that are selling on the commercial market also have products that have been inserted into the military or are being tested for insertion. In addition, there are 20 projects that we felt had good prospects of addressing both markets in the future. Thus, 36 projects out of the 113 are either successful, or show a potential for success, in both the military and

commercial marketplace. Only five of the 113 projects are thought to have failed in both markets.

2. The TRP maintained a high level of military/defense utility. Military/Defense Utility is a measure of the value of a product or technology to the military. Utility does not necessarily result in transition, but is an important step along the way. Nearly all projects began with criteria for military utility. Some failed to meet that criteria and others were too immature to forecast whether or not they would meet it. The study revealed military value in 85% of the 92 projects sufficiently mature to judge this characteristic.[32] In 38% of the 92 projects, a Military Service has accepted the cost and performance specifications that constituted military utility.[33] Instances where projects delivered technologies or products that reached higher levels of performance than original goals demanded are discussed below.

- *Uncooled IR:* The resolution goal was a sensitivity of 0.1 degree at F1 aperture – the project realized 0.055 degree.
- *Portable Shipbuilding Robotics:* While the unit cost target was $40K, the current cost is $5K. A 40X reduction in programming required was also better than expectations. The project resulted in more than seven patents.
- *Advanced Composites Bridge:* Prototype testing results forecast costs 18% lower than targeted cost and weight reductions 14% greater than target.
- *Affordable Composites for Propulsion:* Weight savings of 20% were sought – 0% to 44% was realized. Damage tolerance 10X better than honeycomb was accomplished, rather than the targeted 3X better than honeycomb.
- *Air Quality Monitoring System Using a Neural Network Based FTIR Spectrometer:* A standoff range of 5 km was needed; 18 km was demonstrated.
- *Consortium - The Path to a Globally Competitive MCM Industry in the U.S.:* Values accomplished for processed area, number of interconnects, and clock speed were 1.5, 1.4, and 1.2 times target values, respectively.
- *Diver Alert and Tracking System:* The targeted system cost was $75,000, while the final cost is estimated at $10,000.
- *Experimental SONET OC-192 (10 Gb/s) and ATM Self-Healing Ring:* Distance criteria for 10Gb/s was 10km. The project realized 100km.
- *Industry Common Building Block Electronic Modules:* Density criteria was "better than present." The project accomplished 3-5X present values.

[32] The remaining 21 projects were either too immature to judge military utility or it was not possible to quantify this metric.

[33] We gave credit for acceptance if the military was actually buying the product or technology.

- *Low Cost Packaging Based on Area Bonding Adhesives with X,Y and Z Axis-Conductivity:* The project realized thermal shock tolerances that are 5X better than that of current technologies, versus the goal of "better than."
- *Low-Power, High-Resolution, Portable Ultrasound Imaging System:* The target cost was $100K. It is now projected at $50K. Size reduction improved by a factor of ten. The power demanded is 10 watts versus the original goal of 40 watts. The resolution is 5 nanoseconds versus an original goal of 25 nanoseconds.
- *Precision Laser Machining:* Brightness is 10X better than competition and drilling speed is 6X better than competition. "Better than" were the goals.
- *Pyrotechnic Actuated Vehicle rescue Equipment:* The project delivered a market for pyrotechnics, plus a Laser Igniter System (through a complimentary project for the Army).
- *System for Noninvasive Arterial Blood Gas Measurement:* Test speed criteria was 30 minutes, while the project realized one minute.

3. DARPA's tri-service role was highly regarded, but transition strategies were often lacking, or were poorly executed. Many industry project managers (55% of the 104 that responded) felt that the tri-service representation offered by DARPA, as an OSD agency, was valuable. But, there were comments on project managers' lack of help in reaching Service customers and few transition strategies were articulated. This resulted in instances when we felt that products and technologies that could have been inserted into the military with additional effort and a plan, failed to transition. In some cases, the government project managers were more interested in the technology than its application. More often, it was a matter of priority – successful project completion usurped the attention of the government participants to the detriment of the immense effort, networking, and planning that it takes to successfully transition products into the Services. Transition of products under the TRP, as in nearly all DARPA programs, is often highly dependent upon the individual DARPA project manager, his commitment of time, his contacts within the Services, and his skills in developing and pursuing an effective transition strategy. It was suggested by some industrial participants that DARPA should have considered inserting military end-users (on many projects Service laboratories were part of the consortium) or paying the Services to develop and implement a transition plan. Some examples of TRP project experience on this issue follow:

- *Air Quality Monitoring System Using a Neural Network Based FTIR Spectrometer:* DARPA's participation (as a tri-service representative) was helpful, but the lead company wished that DARPA could have more actively promoted its product to other government agencies with environmental-monitoring or site-cleanup responsibilities.

- *Next Generation High Resolution & Color TFEL Displays:* Planar indicated that it had developed good interactions with the Air Force, the Army Soldier Systems Command and the Army Tank Automotive Command (TACOM) during this project. For example, the ASEP technology display for the M-1 tank will also be inserted into Air Force fighter cockpits in a follow-on program for an F-16 display. Historically, the Army has been the biggest user of electroluminescent displays because of their temperature tolerance and their resistance to shock and vibration.

- *Industry Common Building Block Electronic Modules:* The Navy's involvement was very beneficial, according to the consortium leader. Although neither the Army nor Air Force were directly involved in this project, the DARPA project manager served as the interface to the Air Force's HITEMP (High Temperature) program which has closely related objectives. This DARPA interface has assured that the Air Force program managers are well aware of the progress on this program.

- *EcoScan - A Tunable IR Laser Remote Sensing System:* The participation of DARPA and the Army made it easier for Rockwell to talk to the Navy and Air Force, especially as there was no significant rivalry among the services. The project's DARPA affiliation definitely broke down barriers and let the consortium look at requirements across the board.

- *Development/Application of Advanced Dual Use Microwave Technologies For Wireless Communications And Sensors For IVHS Vehicles:* According to the consortium, there was no participation from the Army or the Navy. Even though the agents, Department of Transportation and FCC, did show up for reviews they revealed no substantial interest in the program. This aspect of the TRP project was disappointing.

- *Interoperability Testbed For Diagnostic and Prognostic Maintenance of Equipment and Processes:* The DARPA project manager stressed the importance of finding the right person to run such projects. He pointed out that there is no real DARPA procedure to report out on TRP-type projects through the DARPA chain of command, as he must do every six months for most DARPA core programs. Also, there's no path for making these projects visible. They also need a Service champion or a "landing pad" in the Services. For these projects, there was no service end-user in the room, so an overloaded DARPA project manager has the burden of making the DoD contacts needed for transition.

- *Fly-By-Light Advanced Systems Hardware (FLASH) Program:* The FLASH project developed components useful to all three services -- the Air Force (F-15), the Navy (F-18 fighter), the Marine Corps. (AV-8B), and the Army (AH-64 helicopter), so this role was important.

- *Amorphous Silicon Medical Imager:* Service personnel did not participate in the program.
- *Low Cost, High Density, Sequential Build PWB Manufacturing:* No active participation by the Services, but a Navy CRADA was involved in starting the project.
- *LEGOS: Object-based Software Components for Mission-Critical Systems:* Multiple demonstration sites now exist to demonstrate the software that was developed with the involvement of all three Services.
- *Dual Use Sensor Technology for Air Transportation System Capacity and Safety:* The consortium felt they needed no help in reaching their military customers, but they agreed that DARPA should lead a program like this in a centralized manner. This is principally because of the need to do business in new and innovative ways, and it is probably the only way to get commercial companies involved. It is important to have an agency like DARPA to serve as a clearing house for good dual use ideas. They also expressed a fear that, without a unified program, the commercial participants would not get access to the right military people.
- *Object Technology for Rapid Software Development and Delivery:* There was a lot of uncertainty within the consortium that the federal government supported their project. While their direct customer (USAF's Rome Lab) liked the technology, they perceived little response from DoD or the government above the level of Rome Lab.
- *Surgical Simulation for Limb Trauma Management:* MusculoGraphics felt that it could have benefited from more guidance from the military user.
- *Gamma Ray Imaging System for Nuclear Environment Monitor:* The Services did not get involved since DoE administered the project from INEEL (Idaho National Engineering and Environmental Laboratory). The DARPA program manager was apparently unable to find contacts in the Services that would have had an interest in the project.
- *Low Cost Electronic Packaging Through Systems Approach to Ball Grid Array Package Assembly:* The consortium saw little participation from the Services. Program reviews included only DARPA and NASA participation.
- *Computer-Aided Earth Moving With DP-GPS:* According to Leica, the project's "dual use" and "military co-benefit" aspect suffered from at least two factors. The team's proposal focused on military-construction needs to cover the "defense utility" side. But the Army Corps of Engineers at the Waterways Experiment Station (WES) had no funds for the project and requested $50,000 from the CAEM team to pay for their participation. As the team could not do this, WES participated only as an observer. DARPA's

choice of NASA-Ames as executive agent (due to Ames' expertise in high-speed processing of DP-GPS signals) further diluted the project's "military benefit" side. They felt that such dilution of military benefits would not have happened under a conventional defense contract.

4. Projects with compelling commercial goals require <u>continuing attention</u> by the government program managers. According to interviews with industry, the commercial market was viewed as more lucrative than the military market. That does not imply a disinterest in military sales. However, industry's focus on satisfying the commercial customer requires the government project manager to become more skilled in evaluating and making performance and cost tradeoffs between the two markets. Maintaining military utility (e.g., ensuring essential military features and adapting military operations to commercial standards and performance) is a crucial project manager function, even if it does not guarantee transition. Frequently, the military cannot afford to buy a dual use product until it is available on the commercial shelves, so the government must often remain involved in such projects until their output reaches the marketplace. The more successfully the project manager has maintained military utility, the more likely is a transition.

Examples presented below are projects that will see, or have seen, the end of government funding well before productization. All have excellent potential for defense application and many have features that make them especially useful to the military.

- *Computer Aided Earthmover:* The development of a Differential GPS-based system to autonomously position an earthmover blade horizontally and vertically has been completed by this TRP project. Now it is being incorporated into Caterpillar hardware and will be available for purchase by the Army Corps of Engineers and Combat Engineers. Transition of this technology will occur through the commercial shelves because the feature will be available on standard earthmoving equipment.
- *Electronically Controlled Variable Displacement Vane Pump (VDVP):* The technology is a pumping system which can vary the amount of fuel delivered according to engine needs. This permits the elimination of the air/oil coolers and conserves the vital air flow through the fan. The VDVP also permits a substantial simplification of the control system with the elimination of complex metering valves, offering a significant reduction in fuel system cost. It is expected that the VDVP will be market ready by 2001.
- *Precision Laser Machining (PLM):* PLM tools are being developed for drilling cutting, welding, and heat-treating a variety of mechanical and composite parts on manufacturing assembly lines. This technology will enable higher precision and greater tooling speeds than are currently available, thereby creating a revolutionary U.S. manufacturing capability.

Projected benefits to platforms like the F-119 engine for the F-22 include more efficient cooling, doubling of component life, and reduced life cycle cost of $100M per engine fleet. Improvements in the cooling channels are expected to leads to a 3% increase in fuel efficiency. However, the primary initial application will be in the automotive industry where reductions in manufacturing costs of $185 per car are possible.

- *Integrated Small Precision Optics Manufacturing Technology:* Micro-optics can often replace spherical optic elements, while micro-scanners and narrow-band spectral sensors have potential military utility and market potential in small scale automated adaptive systems. For example, small, lightweight scanners and microoptics can be used for aircraft crew head-mounted displays (HMDs) that can affect military systems worth millions of dollars. Similarly, compact wavelength-selective devices will allow the development of laser threat warning receivers, optical identification of Friend or Foe, multi-wavelength imaging missile seekers, and many more military applications. However, the initial applications are all commercial. Polaroid has incorporated microlenses into their commercial laser configuration and micro-scanner technology is being pursued for productization by three consortium members.

- *A System for Noninvasive Arterial Blood Gas Measurement:* Accurate, noninvasive, arterial blood gas measurements have been demonstrated on humans. Noninvasive monitors would eliminate the need to draw blood from the wounded on the battlefield, thereby reducing the incidence of infection and saving time and cost. Such a capability could reduce the morbidity and mortality of combat casualties. Realization of this technology for military use will happen only after clinical tests are conducted for civilian casualties.

- *Low Cost, High Performance Tooling by Three Dimensional Printing (3DP™):* Rapid fabrication of tooling by and commercialization of the process and equipment for use by the U.S. industry is the goal of this project. If successful, this process will reduce the print-to-part time from two-to-six months to one week. This will yield an interesting prospect for the Navy to greatly reduce inventories by using the 3DP™ machine to fabricate spare parts when needed. It will require time, however to cycle through the commercial sector and back to the military.

5. Despite skepticism expressed by many critics of dual use, government <u>does</u> influence corporate investment decisions. In many cases, DARPA's backing persuaded corporate boards to sponsor one of their divisions to initiate a project. Of course part of this persuasion comes from the cost share the government contributes, but these boards were also impressed by DARPA's reputation. This ability to influence corporate decisions is

usually a benefit, but it must be used carefully. The following projects are instances where DARPA was able to influence corporate management to initiate a project, or to dramatically change project goals to better address military needs:

- *Digital X-Ray:* According to General Electric (GE), there are many more ideas in their company than money to pursue them. This program was chosen partly because the government was interested and willing to cost share. GE has a requirement of an 18-20% return on investment (ROI) from a project. Since cost share reduces that investment, it reduces the required return. The original goal of the project was to address the market for vascular x-ray. This is a large commercial market that demands a smaller digitizing panel than a whole chest x-ray. While GE was comfortable with this strategy, the DARPA project manager insisted that battlefield requirements called for full chest coverage. The GE corporate board agreed and the project was successful in developing the product.
- *The Integral Motor/Propeller Propulsion System* was to use Westinghouse Electro-Mechanical Division's (WEMD) expertise in designing "canned" pumps for nuclear vessels to develop and market a "canned" propulsion system. DARPA was helpful in convincing the corporate board to enter into the project, even though they had initial doubts about its commercial efficacy. Unfortunately, it was decided after beginning the project that the commercial market was not suitable and the company terminated the project.
- *Uncooled IR*: DARPA ensured that the thermal stabilizer (by Marlow) was sufficiently rugged for military use. If the project had been aimed strictly at the commercial market, rather than being conducted as a dual use effort, this component would not have met military specifications.
- *Next Generation High Resolution & Color TFEL Displays:* Planar originally had selected a generic flat panel display for development, but under the TRP, changed to one with immediate military utility.

B. Business Approach

Major Finding: ***Business-like approaches and practices used in the TRP were well received and are crucial to program efficiency and to attract the interest of commercial industry.*** When compared with normal DoD technology development processes, 43% of the consortium leaders specifically stated that dual use processes used in the TRP were faster, 68% believed they were easier to perform, and 36% found them less costly to manage. Overall, 93% of the 101 consortia responding agreed that there were benefits to the military of using the dual use approach in the project. But, interviews revealed confusion on DoD's commercial leveraging strategies and goals. Concern was voiced that dual use, and the new business practices it promoted, would fall into disuse in favor of more conventional DoD acquisition and management processes.

TRP failed, however, to initiate a continuous assessment process. This could have provided important insights and could have facilitated corrective actions, when needed. We feel that an ongoing assessment of the TRP would have produced lessons learned in real time. These could have been shared with all project managers, adding emphasis to transition, for instance, and allowing fine tuning of business and management processes. We believe that such an assessment would have enhanced the value of the TRP, yielding a larger number of product insertions into the military.

- *Dual Use Sensor Technology for Air Transportation System Capacity and Safety:* This consortium felt that, if pursued through a normal defense program, costs and time required would have been much higher and it would have been more difficult to address the commercial market. Part of the benefits to the military resulted from the use of commercial practices and common grade parts that would not have been allowed under a conventional military program.

- *Low-Cost Flip Chip:* The consortium felt that the project was considerably faster to set-up and much easier to manage than a traditional military contract. According to the consortium leader, agreements were made among the participants and were not encumbered with numerous military specification or FAR regulations. Considerably less funds were expended for accounting practices than on a traditional program. The consortium used the companies established commercial accounting systems that conform to normally accepted accounting practices. Some of the companies would not have participated in the TRP if it had been a traditional program. Reports were faster and conformed to best commercial practices. The consortium members (with DARPA PM approval) helped direct the program to make maximum ROI.

- *Model Based Control and Diagnostics:* According to the consortium leader, TRP projects take more time to form, especially when negotiating payable milestones. Another distinguishing feature is that a DoD project manager or agent for a TRP needs to be much more sensitive to commercial business considerations -- as opposed to pure technical performance on a conventional DoD contract. The manager really needs to be a businessman. In this project, it was a useful discipline to see first-hand how conscious the commercial partners were regarding their ROI. They needed to recover not only what they put into this project but also had to insert it into a much larger market of corporate products.

- *Integrated Small Precision Optics Manufacturing Technology:* There were many problems with the Office of Naval Research's (ONR) contracting offices concerning the Other Transactions Authority (OTA) used for TRP contracting. Although it had been negotiated as an OTA, ONR's legal counsel would not contract in that mode. Consequently, the agent chose to sign it as a normal contract but ran it as an Other Transaction. Since a

consortium requires management by consensus, the ability to (re)negotiate flexible milestones is important. For example, one university in the consortium couldn't make its payable milestones -- a problem often found in university work. So, even though this was controversial, milestones were redrafted to permit payment. For agreements, the choice of executive agents for R&D-intensive contracts like this one is crucial. The agent must be credible and command the respect of the industrial community with whom he or she is working. Ideally, the agent would come out of the funding organization itself. The agent must have a professional reputation, a demonstrated ability to add value and the gift of adaptability. Flexibility also facilitates the solution to personnel problems. For example, one Boston University researcher had a stroke and couldn't meet his assigned milestones. The project was adjusted to give him time to recover.

- *Customer Driven FED Manufacturing Partnership:* The consortium found the TRP process very effective, providing them with crucial credibility with outside investors. It was largely responsible for their success in raising ten times as much private money as that furnished by DARPA. They judged the whole process to be very efficient, with clear milestones and business criteria, along with efficient contracting and good DARPA management.

- *UV DIAL LIDAR:* A consortium member asserted that, "without TRP, this project would have cost three times as much and required three times as much time. The government people were terrific: they really wanted us to succeed. We feel we could speak very freely and candidly with them. A standard contract would have cost us candor."

- *Low-Cost Packaging Technology for Automotive Electronics:* Comments from consortium members: Auburn University indicated that the project enabled four team members (AMP Circuits, Avex Electronics, Delco, Chrysler) who are not military suppliers to participate in a DoD-funded project. Auburn and Allied Signal were long-standing DoD contractors, so they could operate under standard DoD contracting rules; the others could not do so. The project was Chrysler-Huntsville's first DoD contract. It was not a major accounting burden. The company treated it as a best-effort contract and committed a 2/3 cost share, exceeding its requirement. Delco historically has not performed defense contracts. It now participates in, or leads four TRPs that cover, among other topics, low-cost flip chips, MCMs on laminate (MCM-L) and laminate development.

- *Fly-By-Light Advanced Systems Hardware (FLASH) Program:* Boeing has two interactive TRP projects for next-generation flight control systems: FLASH and Vehicle Management System Integration Technology for Affordable Life Cycle Cost (VITAL). Both had the same manager, who found the TRP process less costly, faster and easier.

- *E-Smart System for In-Situ Detection of Environmental Contaminants:* According to the consortium lead, General Atomics (GA), the TRP process was initially harder for the company and the team, in part because of cost-sharing and IPR issues. Once the TRP award was underway, GA found it faster and cheaper than conventional defense contracting. GA found TRP more flexible in scope, especially in changing situations where program managers must revise their strategy. Minimized bureaucracy was another plus. GA found DARPA and its agent, DoE's Idaho National Engineering and Environmental Laboratory (INEEL), very cooperative and flexible during this project. Major differences between TRP and non-TRP agreements included, (a) the multiple contacts with potential sponsors and users that GA could make under its TRP project, thus potentially broadening the project's scope; and (b) the modest reporting requirements of TRP projects. The TRP was a novel experiment for a defense company, but GA management might not do it again. A commercial company may feel differently. The project was part of the second round of TRP awards. At that time, there was less stability in the defense industry and major defense downsizing was underway. But now there is more stability in the defense sector and programs like TRP are less attractive. For the same corporate money invested in this TRP project, GA could try to win multiple conventional cost-plus defense contracts. GA managers also must wonder if TRP is to be a one-time experiment. The absence of a guaranteed initial market is another disincentive. For example, when GA completes the E-SMART project, it has to start marketing all over again because there is no assured federal market.

- *EcoScan - A Tunable IR Laser Remote Sensing System:* The consortium did not find TRP to be faster, less costly, or easier. As an early TRP awardee, they found it difficult to pioneer cost-sharing. It was hard working issues out, although it became easier after they participated in a few TRP projects and their corporate mindset and accounting system could handle them. Because EcoScan was an early TRP project, it experienced a steep and frustrating "learning curve" among the government organizations involved with it.

- *Next Generation High Resolution & Color TFEL Displays:* This project featured a vertically integrated structure that linked basic researchers at DoE labs with larger companies to integrate flat panel displays into salable computer or end-item products. The consortium lead indicated that "we have never seen a program that ran as well as this one. However, we found it a very expensive program for us because of the cost share requirement." Planar stated that they had become a big proponent of dual use. DoD represents only 5% of their business base (out of a total of 200,000 displays per year). But, DoD lets them do the leading-edge R&D that keeps them technically current and, as a result, DoD gets better products.

- *National Academic Medical Center Information Collaborative:* The TRP management structure enabled the consortium to change it's leadership from Bell Atlantic to SAIC. It also changed its focus from finding ways to expand the depth and geographic coverage of Bell Atlantic's OASIS medical-database system to finding ways to search across widely varying medical databases and to aggregate large virtual databases from a single workstation.
- *Microfabrication of Ophthalmic Surgical Knives Process Development and Mechanical Design:* This small ($130,000) project fell on difficult times. The only commercial partner pulled out and the agent, NSF, issued a cost shared grant to pursue the program as a university research project (which resulted in little government project manager influence). Unfortunately, the project failed when the liquid chemical etching process did not succeed for sapphire.

Subsidiary conclusions include:

1. In particular, innovative agreements (Other Transactions and Cooperative Agreements), contributed to TRP's success. Of the 108 projects responding, 76% preferred TRP's innovative contracting vehicles (Other Transactions or Cooperative Agreements) to conventional contracting vehicles. We felt that this judgment was more negative than it would have been if implementation had been more effective and faster. This weakness, exacerbated in some cases by overly cautious contracting procedures, was typical of most agents outside of DARPA. But, once in place, virtually all participants believed they worked extremely well. There have been recent rumors that the use of Other Transactions will be curtailed. In our view this would be a mistake. These agreements were a principal tool in the TRP's success and their loss or reduced use may well dampen the interest of commercial industry at a time when DoD should be trying to improve its reach into that community. Many commercial companies will not work with the DoD if FAR contracts are dictated. Examples of strengths and weaknesses in TRP's business processes are offered below.

- *Integrated Opto-Electronic Modules (IOEM):* Other Transactions provide the flexibility needed to adapt to changing programs. Originally, a division of Allied Signal, Inc. was the consortium member responsible for developing and marketing the military product, the fiber optic gyro (FOG). Some months into the program, Allied Signal became interested in an alternative technology to fiber optics for the gyro design. Instead of simply dropping the FOG, however, the consortium found a small company named Fibersense to carry out the original plans for development. This was accomplished simply and quickly (after receiving the government program manager's agreement). Under a normal contract, this would have become quite burdensome. The ease with which this change of consortium members was made is characteristic of the power and flexibility of the Other Transaction.

- *Amorphous Silicon Medical Imager:* Varian Associates, the consortium lead, indicated they would enter into a TRP-like project again, but only if it would be done under the Other Transactions form of contracting. They felt that TRP programs conducted under Other Transactions provide far more flexibility to the project manager to initiate and carry through necessary changes than is possible under normal FAR controlled contracts. Furthermore, since the contractors share the costs of TRP projects, they themselves do a far better job of policing the effort and expenditures than is possible for a DARPA PM. The visibility that this kind of a contract generates in a company also helps to get a first rate job done on the contract; CEO's even show up at contract review meetings.

- *Commercialization of DoD IUA Vision Computer: An Enabling Technology for CAD-Directed, Vision-Guided Robotics for Flexible Manufacturing:* The primary benefit of the Other Transactions contract in this project was greater flexibility in dealing with problems and issues before they became serious. This flexibility allowed for re-planning aspects of the TRP that enhanced responsiveness to changing government perspectives, the marketplace, and changes in technology. This consortium revised its SOW three times.

- *Low-Cost Plastic Packaging:* According to the participants, the program was not bogged down with numerous military contract clauses. Best commercial practices were used to develop the program and agreements. The ability to include work at Sandia, RelTech and universities also benefited the program.

- *Low Cost Electronic Packaging Through Systems Approach to Ball Grid Array Package Assembly:* According to the consortium leader, it took too long to initiate the agreement, but once in place, the overhead to run the project was low and the requirement for documentation was less than on a normal contract. The latter fact made the contract easier to perform and resulted in more work accomplished for each dollar spent.

- *Uncooled IR Microbolometer Sensor Cost Reduction Program:* Lockheed Martin is presently negotiating a dual use agreement with CECOM, but is frustrated by the lack of flexibility to execute an Other Transactions project. They felt that DoD should educate the Services on how to contract under Other Transactions in a spirit that is more representative of DARPA's implementation of that legislation.

- *Computer-Aided Earth Moving With DP-GPS:* The project was slow to get moving. DARPA announced the team's selection in October, 1993 but it took 17 months to get the agreement signed (as a cooperative agreement with NASA). NASA took the position that once the TRP money had been

transferred from DARPA, the agreement was a separate NASA contract. This meant that the team had to rewrite the project's statement of work.

- *Regional Technology Alliance for High Aspect Ratio MEMS Technology Development:* The contracting agent, NSF, could not accommodate the unconventional contracting practices employed in first-round TRP awards. After almost one year of NSF inaction, DARPA decided to run the project itself and initiated the contract in six weeks. The consortium lead, Microelectronics Center of North Carolina (MCNC), believes that appropriate choice of executive agents is all-important to projects like TRP. In particular, the contracting agents must buy into the contracting method and support it.

- *Air Quality Monitoring System Using a Neural Network Based FTIR Spectrometer:* It took over six months to submit required paperwork, including a "vision statement," information on consortium members, and other required data. The consortium found federal contracting officials generally unfamiliar with flexible contracting.

- *Vehicle Management System Integration Technology for Affordable Life Cycle Cost (VITAL Program):* According to the consortium leader, this project has been less costly, faster and easier -- except when they went to the Navy (NAVAIR) to sign the agreement. At first, NAVAIR would not sign it and insisted on using the FARs. They used their FLASH agreement with the Air Force as a model for this agreement, but reported that it still took six months to get it signed. They persevered because they had as much a stake in this program's success as does the government, so there's a built-in incentive to make it succeed.

2. Rules affecting intellectual property rights (IPR) benefited both industry and government. In particular, by allowing industry to retain rights to the intellectual property generated during the TRP, government gained early access to some of industry's best ideas. Interviews with companies revealed that IPR was a major issue, and is likely to remain so. Resolution of this issue enabled industry to insert ideas and technologies into the project, rather than withholding them or introducing them only after the TRP project was over. Of the 105 projects responding, 97% felt that their IPRs were protected. Examples of the experience of TRP participants with IPR are offered below.

- *Computer-Aided Earth Moving With DP-GPS:* To suggest the necessary degree of innovation in the CAEM project, Caterpillar submitted seven patent descriptions during this project. The company indicated that IPR is its greatest concern in any project. As a corporate policy, Caterpillar will not participate in a project unless it gets complete and exclusive data rights.

- *Customer Driven FED Manufacturing Partnership:* According to the consortium leader, Candescent Technologies Corporation, IPRs represent a huge part of their commercial success. They spent millions of dollars on patents and have filed for 130-140 patents.
- *LEGOS: Object-based Software Components for Mission-Critical Systems:* According to the consortium, the struggle to establish their IPR with DoE almost ended the project. The standard DoE IPR contracting policy was used. Key development by IONA and I-Kinetics was performed outside TRP effort and made available through commercial licensing channels.
- *Technology to Produce High Performance/Low Cost Interconnections for Flip Chip Attach:* Agreement negotiations were long and hard because of IBM's concerns over intellectual property rights, access to the technology by IBM's overseas operations, government audits, and government march-in rights. In the end, OTAs made it possible for IBM Endicott to participate in a government program. They normally do not work on government contracts.

3. Cost Share benefited government and industry. It is axiomatic that the industry's cost share reduces the cost of the development project for the government. What was not so predictable is that most of the responding 111 companies (77%) believed that cost share benefited them. This was principally because they believed the retention of IPR and a high-level of project control were important to them (in order to better address the commercial marketplace) or they felt they would not have been selected under a conventional military solicitation. We believe the industry cost share could sometimes be justified at a lower portion than the 50% demanded by the TRP (e.g., where the commercial market may be small relative to that serving military needs). There was much sentiment for requiring cash for cost share, rather than in-kind contributions. Comments on cost share are presented below.

- *Computer-Aided Earth Moving With DP-GPS:* Leica indicated that 100% funding by the government would have changed the flavor of the program. They felt it was important to keep the government off their backs, so they were delighted with less government participation, which would have slowed them down. The consortium did not want the government to view the project as a delivery against specifications. Cost-sharing gave them more flexibility and disciplined the project considerably, because they needed the commitment from each company manager to go forward.
- *Aircraft Surface Contamination Detection Technology Advancement:* The industrial cost share provided corporate management a lot of leverage. Further, the lead company, Rosemont indicated it would have abandoned this effort without government cost share.

- *Technology to Produce High Performance/Low-Cost Interconnections for Flip Chip Attach:* Cost share enabled this project. At the time of the TRP Broad Area Announcement (BAA), IBM was in a very difficult period, but they would probably fund it as a commercial venture today.
- *Next Generation High Resolution & Color TFEL Displays:* Cost share worked well, but the requirement for 50% match was a very tough one for a company of Planar's size. They felt that a 25% match would have been much easier, especially since in the defense business the procurements take a long time – and during that time the company stays in negative financial balance.
- *Regional Technology Alliance for High Aspect Ratio MEMS Technology Development:* Cost sharing prompted a deeper commitment to this project on the government side and also kept the company focused. However, the requirement for an up-front cost share was difficult for small companies (and this consortium included a small company and a university-based non-profit). What made their participation possible was the willingness of IBM and Louisiana State University to pay more than their cost shares.
- *Integrated Opto-Electronic Modules (IOEM):* Because of the cost sharing and a Joint Management Committee to run the contract, the contractor is much more responsive in finding solutions to problems that develop during the course of the contract. This feature eased the PM's burden considerably.
- *EcoScan - A Tunable IR Laser Remote Sensing System:* Rockwell expressed the opinion that co-funding can perversely de-motivate companies. Rockwell management believed that when a customer pays all the costs, the customer rates the project as a high priority ("…if the government didn't fund it 100%, it did not plan to buy…"). By contrast, a co-funded project would represent a lower priority for the customer and the company would read such signals. So, Rockwell might even consider not participating in a potential co-funded project. EcoScan was viewed by management as a real drain on corporate people and funding, so Rockwell made the decision not to commercialize it. In addition, Rockwell's accounting was not geared to co-funded projects. Rockwell was unwilling to install a separate accounting system for commercial EcoScan sales.

4. Consortia were a success. A great majority of the 108 companies responding (86%) appreciated the value of partnerships, but many cautioned against making consortia a requirement for selection. Consortia involvement was often a new experience. Some companies indicated that they adopted this approach simply because it was demanded by the solicitation. Most of these companies professed that they became advocates after realizing the value of added perspectives and skills. This seemed particularly true when the consortium brought together defense and commercial firms.

The extra management burden of achieving consensus was often cited as the down side of consortia. For example, trying to manage a consortium that included industrial giants may overwhelm a small business or university acting as consortium lead, or even as an "equal partner." The following are examples drawn from the TRP experience in consortia.

- *Low-Cost Packaging Based on Area Bonding Adhesives with X,Y and Z Axis-Conductivity:* The partnerships were important in providing the required cost share and in bringing in the needed talents to conduct a thorough evaluation of the technology. Auburn University had the equipment and did the evaluations. At the other end, it was highly beneficial to be able to hand off the technology to a manufacturer who also conducted necessary market surveys.
- *Low-Cost Plastic Packaging:* This project provided the opportunity for National Semiconductor to bring together their entire supplier base. It was the first time this has happened in the semiconductor industry. This partnership provided everyone with insight into all the steps necessary to complete an IC. It was a catalyst for bringing people together to solve problems at each stage of the IC assembly process. The consortium felt that it allowed their people to stretch the bounds of their thinking.
- *Regional Technology Alliance for High Aspect Ratio MEMS Technology Development:* Partnerships were judged by the consortium leader as "mostly worthwhile." The core fabrication group (MCNC, Louisiana State University Center for Advanced Microelectronics and Devices) worked well. However, the Alliance experience with other groups like the Naval Surface Weapons Center was mixed. The Alliance ended up with a large group of members, including DoE's Oak Ridge National Laboratory with its large MEMS program, and DoE's Brookhaven and Lawrence Berkeley National Laboratories, which host advanced synchrotrons.
- *Digital X-Ray System for Trauma and Battlefield Applications:* GE feels that consortia with large numbers of people are difficult to form and run. If a company such as GE has the capability to cover all facets of the program, they should not be required to form a consortia. The government should facilitate a consortia if they feel it is necessary, but not require one.
- *E-Smart System for In-Situ Detection of Environmental Contaminants:* General Atomics (GA), encountered difficulty directing the consortium -- in contrast to the well defined prime/subcontractor teaming of conventional contracts. But, it would have been hard to recruit one team member, ISCO (which does $40 million in annual commercial business), under a standard government contract. ISCO saw federal contracting rules as a nuisance.
- *Dual Use Hydrostatic Bearing Program:* The division of United Technologies Corporation leading this project consortium stated that

teaming with Pratt & Whitney was a good experience for their engineers. In particular, they had an interest in knowing more about activities at Sikorsky in gears and with Pratt & Whitney on impellers.

- *EcoScan - A Tunable IR Laser Remote Sensing System:* Rockwell experienced the risks of such teaming, especially when project teams are assembled quickly with no time to perform due-diligence checks on team members and the status of their technologies (Rockwell felt it had only three weeks to assemble its team). This demonstrated to them the need to build consortia carefully. Rockwell felt that the mandatory TRP teaming was tough because of their belief that the teams had to include universities, a government or military partner, and a small business to "fill in the boxes." We feel that this is too conservative an interpretation of the BAA language.
- *Aircraft Surface Contamination Detection Technology Advancement:* Consortia members brought expertise and insight to the project. In particular, it was very helpful to have end-users on the team, ensuring that the development stays focused and provides exactly what the user requires.
- *Fly-By-Light Advanced Systems Hardware (FLASH) Program:* Consortia were important and effective in both FLASH and VITAL projects. The FLASH team had 16 members, and the VITAL team had 11. All team members signed the same memorandum of agreement – an impressive accomplishment.
- *Low Cost Electronic Packaging Through Systems Approach to Ball Grid Array Package Assembly:* Ultra Clean claims it could not have done the program alone. Indy Electronics provided all the testing and eventually bought one of the machines.
- *Air Quality Monitoring System Using a Neural Network Based FTIR Spectrometer:* The consortium only had two members (AIL Systems and MIDAC Corporation). Both had worked with each other before. However, complications arose from the size imbalance between the two companies. MIDAC's annual business activity totaled $2M to $3M, yet it was teamed with a company (AIL) that averaged $150M to $200M in business per year. This disparity created problems.

5. Performance milestones worked well, but care and flexibility is needed for high-risk projects. Performance milestones were generally judged to be a good tool. For example, they were seen as cutting the burden of normal government reporting requirements. But performance milestones work well only if formulated carefully and applied with flexibility. Many companies had difficulty with performance milestones where project risks were high. Small businesses were particularly affected because of the lack of financial cushion. Under these circumstances, rigid milestones become essentially a

fixed-priced contract approach – inappropriate for high-risk projects. When this situation occurred, it was often mitigated by government project managers who felt empowered to negotiate modified milestones. Some comments on this issue are offered below:

- *Dual Use Sensor Technology for Air Transportation System Capacity and Safety:* The consortium felt that progress payments, keyed to performance milestones turned out to be risky. This process requires a learning curve for both government and proposers.
- *Customer Driven Field-Emission Displays (FED) Manufacturing Partnership:* The consortium was allowed to reach milestones out of sequence and to manage according to intent versus managing "to script."
- *Demonstration of Universal Electric Transportation Subsystems:* Given the technical risks of this project, it may have been useful to have provisions for modest upward cost reevaluations if these are linked to design improvements and refinements that would otherwise be frozen out by early cost-vs.-technology decisions. For example, NovaBus' contract was interpreted by the government agent as a firm-fixed-price (FFP) contract, when it actually fit somewhere between FFP contracting and cost-plus-fixed-fee (CPFF) contracting.
- *Miniature Filters For Wireless Networks:* This consortium felt that performance milestones were not appropriate for the effort, since it was a technology development project -- and higher risk than technology application. Essentially, it was treated as a FFP R&D contract. This can be mitigated to a large extent by a strong commercial goal, if this goal is represented well in the performance milestones. Another aspect is the need for a willingness to change the milestones as the project matures and is driven in different directions by technological findings.
- *Uncooled IR:* The Consortium had high regard for "payment by performance" milestones; all members were willing to "live or die" based on their ability to meet common milestones. But, flexibility was important to shift emphasis and schedule in order to meet business needs {for example, deliveries were not specified explicitly (five to eight units)}.
- *Gamma Ray Imaging System for Nuclear Environment Monitor:* TRP's broad approach allowed the consortium to find funding much faster than it could have under the normal DoD technology development process. Even though DARPA's distribution of funds to DoE was slow, overall the project was run in a very cost-effective way. Milestones were readily re-negotiated and additional funds by the company could be allocated where necessary.
- *Portable Ultrasound Device for Battlefield Trauma:* The ONR agent asserted that the project milestones can impose burdens on small companies.

Because these products have a long incubation time, milestones were made much more detailed to create what became sub-milestone events whose completion would trigger progress payments. He felt that these milestones need to be crafted very carefully at the beginning of the project and that the government sponsor needs to gain lots of trust to get inside and see proprietary data: for example, the manufacturability of the transducer design was a major issue for this program. Such trust is very difficult to build under conventional defense contracting. The company must be comfortable sharing its commercialization plans.

- *Integrated Small Precision Optics Manufacturing Technology:* A university member of this consortium suggested that their graduate student agenda planning required long-term scheduling that was difficult with milestones that may be revised quarterly.
- *SiC Power Electronics for Affordable Next Generation Electric and Hybrid Vehicles:* This consortium felt that the government should be willing to change the milestones as the project matures and is driven in different directions by technological findings.

6. Program stability was sometimes threatened. When an effort is conducted strictly for the military, the market is specifically defined and the sponsor, the government, takes most of the financial risks. In dual use programs, however, there are two market sectors, commercial and government. Both are important to the government and industry participants. But, both sectors can erect barriers to project completion in the form of instabilities and delays. In this context, industry assumes that they and their government partner should work together to move through these barriers in order to reach production or insertion of the product as quickly as possible.

We found too many instances where delay and instability prevailed, sometimes leading to the failure of projects that would have otherwise been successful. Sometimes this was industry's fault, for example when projects were "orphaned" due to mergers or buyouts by new (and perhaps disinterested) management. Other times it was a government problem. One complaint was that negotiations ended in "cutting up" projects by replacing portions of the basic proposal with options and then abandoning the options, sometimes without completing a critical demonstration of the technology being developed. Another problem was "dead time" between project phases created by a government decision (e.g., Congressional budget holds). The important point is that government must work hard to avoid adding complexity and instability if it is to be viewed as a good partner (and good partners get the best deals in the commercial sector). Comments follow:

- *Portable Ultrasound Device for Battlefield Trauma:* The objective of this project was to develop the technology needed for the first portable, compact, three-dimensional (3D) medical imaging ultrasound system. The first phase

was to develop a prototype and the second phase was to productize and commercialize the system. But, the TRP only funded the first phase, so no instrument for commercial or military use has resulted. However, component parts developed under the program have found their way into commercial use. This convinced the consortium leader that "option year" funding provisions, which are important for projects like this one, need to be firmer. The project needed more assured funding and stability -- and putting critical funding in the "option" category runs counter to that desired stability.

- *ATM Interoperability Testbed for the National Information Infrastructure:* Problems with the TRP in Congress delayed the beginning of this project by six to nine months.
- *Volatile Organic Compound (VOC) Sensors, Communications, Processing and Display:* Project start-up was delayed for 18 months due to the 1995-1996 confrontation between the Clinton administration and the Republican Congress over cooperative government-industry R&D programs like TRP and the Commerce Department's (DoC) Advanced Technology Program (ATP). But, according to the consortium leader, once the contract was in place, it was pretty straightforward, although somewhat less formal than normal contracts.
- *Power Pak:* Martin Marietta Armament Systems (MMAS) sought to combine the Wankel-cycle engine from DoD's Hunter UAV program and a permanent-magnet generator in a lightweight, high-performance, multi-fuel mobile generator set for military and commercial markets. But, this project achieved neither military transition nor commercial success because the government canceled the UAV program.
- *Low Cost, High Density, Sequential Build PWB Manufacturing:* The consortium leader stressed that the government should make every effort to see that their project managers and agents are not changed during the duration of a TRP project.
- *Digital X-Ray System for Trauma and Battlefield Applications:* Linkage with the Services deteriorated when the telemedicine thrust ended at DARPA.
- *Object Technology for Rapid Software Development and Delivery (later changed to Development of Application Software Hierarchy for Reuse):* The DARPA project manager felt that there was a serious disconnect with DARPA's other projects, which tended to "orphan" some TRP projects. DARPA projects are usually initiated by a program manager with firm ideas. But TRP projects often were imposed from above. Also, he indicated that there was a DARPA perception that, while the agency should focus on pushing the leading edge forward to pick the low-handing fruit, these

projects really emphasized deployment and user base, making their focus more commercial than R&D.

- *TI/Raytheon 'Leap-Ahead' Approach to U.S. Flat Panel Display Competitiveness - Field Emission Displays:* At the time of the interview with the DARPA project manager, he was concerned about its possible orphan status, since Raytheon had chosen to leave the flat panel display business. This departure put a very serious hole in his project since it removes a company that for over 40 years has been a mainstay in avionics displays. He felt there must be provisions in TRP for salvaging technology under such circumstances.

- *Affordable Composites for Propulsion (ACP):* Military utilization of this work has already begun after the project supplied a fan cowl door to the C-17. Commercial application is hoped for in the Pratt and Whitney's PW8000 engine and GE's CF6 engines. A TRP funding cut left the construction and test of the largest engine part, the horizontal containment rig, unfunded -- a major impediment to implementation of this technology in the next Pratt and Whitney engine. It may also complicate utilization in the JSF. Even so, we must point out that, while this was a highly funded TRP project (apparently the most expensive of the projects), the goals were extremely ambitious.

- *Technology and Productization Acceleration of Low Cost, Aluminum Nitride Electronic Packaging:* A buy-out of Carborundum Microelectronics caused a delay of about four months. This sale put the project off track; especially in reaching the cost goals. Since Carborandum had been funding the commercial development; its sale meant that the consortium lost its main commercialization driver and its marketing arm.

- *Just-In-Time Maintenance:* This project was thwarted by a disruption of key consortium technical personnel, facilities, resources, management support, and corporate cost share during two mergers of acquisitions. The consortium was trying to find new members and continue its effort to address the commercial market. If this works out, the project can still be a commercial success.

- *Dual Use Hydrostatic Bearing Program:* The NASA agent indicated that there was an issue concerning the two options on this project. He would have preferred that funding for both options would have been made available at the start of the program, so that when the base program was successful the option funding could have begun immediately. As it was, he had to fight for money when the base program concluded. The option was for commercialization.

- *Next Generation High Resolution & Color TFEL Displays:* According to the DARPA project manager, there was a problem with projects that were arbitrarily discontinued by the contractor or government. He worried that

this would happen to another of his TRP projects. When this problem occurs, the company can unload or sell the technology to a successor or replacement contractor, but the people performing the work may not be transferred with the technology. Without this human capital, the technology may not be worth much.

7. Industry's reaction to TRP's foreign participation rules was generally favorable. Out of the 58 projects that considered foreign participation an important aspect of their effort, 52% felt that DoD's rules on foreign participation were helpful. In summary, these rules allowed foreign companies to be part of the consortia under certain circumstances, but they could not be counted in the required make-up of the consortium. More significantly, technologies generated under the project could not be transferred to foreign players. This last restriction caused problems for those industries, such as the "Big Three" automobile manufacturers, that cannot access foreign markets without providing their technology. This is clearly a conflict between defense and commercial aims. It was generally, but not always, resolved. Below are some comments on this issue.

- *Regional Technology Alliance for High Aspect Ratio MEMS Technology Development:* IBM has subsidiaries outside the U.S., including a world-famous laboratory and prototyping facility in Switzerland that has been active in MEMS. Under the ground rules of the project, IBM had to limit its internal distribution of advances funded by the project. So, the guidelines were a problem. IBM's agreements with the nations where their subsidiaries operate discourage them from limiting their technical information to preferred subsidiaries. They compromised by allowing general information on their TRP-funded work to circulate to their foreign subsidiaries, with delays on more valuable technical detail from TRP programs.
- *LEGOS: Object-based Software Components for Mission-Critical Systems:* IONA was a foreign-owned company at the time that the TRP was signed, yet it was allowed to participate.
- *Customer Driven FED Manufacturing Partnership:* The consortia leader indicated that they needed these rules. They facilitated them in negotiating with foreign participants on the right terms by using the argument that DARPA insisted on certain restrictions -- yet DARPA was flexible on allowing their participation.
- *Uncooled IR:* While the consortium members said they believe the basis for the foreign access to technology provision in the TRP rules is reasonable, they were quick to add that the government needs to allow more flexibility to enable foreign participation (i.e., foreign subsidiaries) when it makes sense for the program. Specifically, they felt that the government should not attempt to limit technology sharing with foreign companies, except for

critical technologies. Foreign involvement should be a business decision, not a government mandate -- the program should be able to garner needed technologies from whomever can supply them best. In their words, "The government will be no more successful in legislating boundaries of technical access than it has been in legislating efficiency in manufacturing processes. Industry and economics drive the best decisions, and this prohibition [was] an impediment to optimal performance on this contract." However, while foreign access to technology was a large issue, an agreement was eventually worked out with DoT, the agent, to allow the sale of subassemblies overseas, but not technology.

- *Low-Cost Plastic Packaging:* Often, using an off-shore company would have facilitated faster development because of their existing capabilities. The consortium felt that the government was too narrow in their assumption that all technology transfer is bad for the U.S., particularly where we are playing catch-up with the Japanese in trying to develop a stand-alone infrastructure in the plastic IC area. They also felt that industry participants should be able to transfer technology to wholly-owned subsidiaries of U.S. companies that are located in foreign countries.

- *Amorphous Silicon Medical Imager:* The consortium suffered increased costs because it had to document that no U.S. manufacturer was interested in providing the small number of 100,000 rad hard Application Specific Integrated Circuits (ASIC) that was needed for the project. They eventually were able to buy those circuits from Switzerland.

- *Computer-Aided Earth Moving With DP-GPS:* This project was in the curious position of having two foreign firms in its three member consortium. Spectra-Physics is 100%-owned by a Swedish company; and Leica, which is 100% Swedish-owned bought Magnavox. So assurances were necessary that the program would benefit U.S. workers. (Note: this refers to the standard commitment to employ U.S. government-funded technical advances to at least the production phase in the U.S.)

- *Aircraft Surface Contamination Detection Technology Advancement:* This rule was very confusing to the lead company and not well explained by government personnel. Their understanding of this rule precluded them from working with an interested foreign customer.

8. TRP projects did not duplicate commercial efforts. Only 38% of the 107 participating companies answering this question would have entered into this project as a strictly commercial venture, so the TRP spawned many projects (and products) that would not have existed otherwise. Many of the other 62% suggested that time to market and military utility of the final product were improved by the dual use approach. But, as will be discussed later, nearly all companies were concerned about added programmatic and

funding instabilities and uncertainties due to government involvement. Even so, 95% of the 105 companies that responded would enter into a dual use agreement with the DoD again. Some examples of the synergism between the two markets are presented below.

- *Uncooled IR:* Companies involved in the development of this technology have all agreed that the military market is not sufficiently large to justify continuing research at previous levels. The agreement by the DoD to assist in addressing the commercial market has spurred much activity and has (for half the cost to the government) yielded important improvements over the Low-Cost Uncooled Sensor Program (LOCUSP) prototype, as well as gains in affordability. Also, the consortium lead, Texas Instruments (now Raytheon TI Systems) had decided that the uncooled product could not be developed and produced economically under the military specifications and standards process. They made the decision in 1992 to develop these systems using best commercial practices. The TRP reinforced this effort, yielding better, lower-cost products and features that will support upgrades and repairs with commercially-based practices like off-the-shelf deliveries, warranties, and telephone response lines. If the project had been aimed strictly at the commercial market, the thermal stabilizer (by Marlow, a consortium member) would not have been sufficiently rugged for military use. Raytheon TI Systems said that its detector technology — the heart of the program — would never have been developed without TRP funding. The same is true for the low-cost optics. Raytheon TI Systems stated that TRP has accelerated the commercialization of the handheld product (PalmIR) and has accommodated start-up of the automotive product (NightDriver). The TRP selection of this program provided credibility with the corporate management of all consortium members. Marlow stated that, while they would have responded to any and all inquiries from customers, they have benefited from the fact that the TRP enabled the Raytheon TI Systems/Marlow/Delco consortium to progress at a faster pace. Delco said they would have conducted the program (with or without the TRP) because they see that it has the potential to lead to a profitable product. We noted, however, that Delco depends on Raytheon TI Systems's technical development.

- *Digital X-Ray:* According to General Electric (GE), the project has helped to reduce the time-to-market by five years. Through TRP's cost sharing they were able to accelerate their program. They feel this acceleration is worth several tens of millions of dollars to them by enabling them to beat the competition. They would have pursued this effort on their own, but, military needs on the battlefield would not have been a part of the program. For example, TRP negotiated an agreement with GE to develop a full-chest x-ray, rather than their original plans to concentrate on the easier, faster, and less expensive task of productizing an arterial/vascular x-ray system. Consortium member, EG&G, answered that they would not have pursued

this product for years since payback from other investments is much higher. However, the government's investment support made this project much more attractive.

- *Dual Use Sensor Technology for Air Transportation System Capacity and Safety:* If the TRP had not been available, the consortium would have still tried to get into the commercial market, but they would not have developed and built the radar. They would have continued to work the enabling technology, but application would have taken much longer. Additionally, TRP helped to bring an important production facility on-line.

- *Diffractive Optics Technology for Battlefield Management Systems:* Rochester Photonics Corporation, the leader of the consortium, stated that it would have done something in the area of diffraction optics, but not the broad consortium with the large number of applications of the technology that characterized the TRP project. Time to market would have been much longer. Raytheon and Optical Networks would not have become involved as the time to commercialize their products was considered too long.

- *Computer-Aided Earth Moving With DP-GPS:* Leica and Caterpillar agreed that they would have begun a strictly commercial program, but the product would have been developed much more slowly. Further, Leica indicated that forming a team would have required more time.

- *Portable Shipbuilding Robotics:* The risk and the investment required for both the technology development and the market development exceeded the capabilities of the commercial market. The combination of military and commercial use of the technology was required to make the project viable.

- *Regional Technology Alliance for High Aspect Ratio MEMS Technology Development:* Without this project, LIGA-HIMEMS would have remained a research process only. MEMStech, a recent startup, told MCNC that without the advances driven by this TRP, the company would have been forced to spend one-to-two years in bringing Louisiana State University's Center for Advanced Microelectronics and Devices facility, whose synchrotron is used for MEMS molds, up to speed on the processes that MEMStech needed for its commercial products.

- *Low Cost Flip Chip:* At the time of the award National Semiconductor would not have assembled such a team to attack the problem of lowering the cost of flip-chip technology. This project was effective because it facilitated the cooperation of many companies from material suppliers through semiconductor manufacturers and contract assemblers.

- *LEGOS: Object-based Software Components for Mission-Critical Systems:* This consortium would have tried to pursue a commercial project, but says that it would not have had the resources to move as quickly.

IV. Recommendations

We offer a summary of the lessons we learned from our study of the TRP in this chapter, The lessons learned are in the form of two recommendations and some suggestions on their implementation. This offering is made with the realization that there may well be initiatives underway in the DoD to correct some of the problems cited and to take full advantage of some of the described benefits. If so, we apologize for this oversight and would appreciate learning of them.

A. DoD should place a high priority on full and optimum implementation of dual use throughout the Department. The TRP provides clear evidence of the efficacy of dual use for the DoD. Because of the benefits to be gained (illustrated to some degree in this report), we feel that its proliferation and optimization should be a major goal for all levels of the Department. We are confident that this proliferation and optimization will happen in time, but its implementation should progress with much more efficiency than is the case.

The Dual Use Research Project. The military and industry panel, led by General Al Gray, USMC (Ret.) offered a number of suggestions for implementing dual use throughout the DoD. These suggestions seem as pertinent today as when they were made, the difference being that we have developed substantial proof that the ideas behind dual use are making a difference for the war-fighter. The panel's plan is described in the following excerpt from their report.[34]

"All of the opportunities to benefit the military through exploitation of the commercial sector and the evidence of feasibility provided by the TRP and other programs will mean little if the dual use approach is not broadened in application and infused throughout the Services. The implementation effort must respond to two challenges. The first is to disseminate knowledge in organizing and conducting dual use technology development programs. Much of this knowledge, gathered during the TRP and other dual use technology development programs, is already resident within DARPA, but new insights are needed to determine the best ways to perform these functions inside the Military Services. The second challenge is to learn how to effectively conduct dual use technology and product insertions into military systems. Less experience is evident in this very important arena and much innovation will be needed. It is important to note that this second challenge must involve the weapons systems prime contractors."

"There are at least five facets to the proposed plan to meet these challenges: Policy, Education, Oversight, Institutionalization, and funding." [Specific conclusions included:]

[34] *Dual Use Research Project Report (PIPS-96-3)*, Potomac Institute for Policy Studies, 21 July 1996.

- "…changes required to conduct dual use programs in the DoD are profound and, in many cases, counter-cultural."
- "…The most effective way to embed dual use in the DoD is to implement it through a strong policy statement coupled with a joint Service implementation arm."
- "…It is the judgment of the Panel that, with education and training and a change of culture, dual use should evolve into the primary mode of development and procurement in the DoD."
- "…The implementation effort should ensure the incorporation of dual use practices into all phases of the product development cycle."

The Military and Industry Panel recommendations for an OSD-led joint Service implementation effort, combined with a strong policy statement, has been pursued through the DUS&T and COSSI programs. These programs are indeed jointly administered, but OSD's role could be stronger and better defined in terms of how it will contribute to proliferating dual use and the part it will play in helping the Services to maximize its effectiveness. Unfortunately, congressionally-mandated quotas for dual use expenditures, expressed as a percentage of Service 6.2 budgets, seem counterproductive. This strategy has resulted in a loss of funding flexibility by DoD and a consequent "Catch 22," in that Services feel their enthusiasm for dual use (and acknowledgment of its success) may be "rewarded" by increased quotas. Suggestions by General Gray's panel and interviewees during this study led to some suggested OSD implementation actions:

1. Commercial leveraging goals and strategies should be stated more clearly to the Department and to industry. As indicated earlier, we encountered confusion in both government and industry concerning DoD's intent and strategy for commercial leveraging. Many consortia suggested that more high-level government guidance was needed in all aspects of the TRP activity – from soliciting proposals to codifying Other Transactions and Cooperative Agreements to evaluating milestones. We suspect that this need for guidance exists throughout all areas of commercial leveraging at the DoD. An action that might be taken is to publish a new DoD report on the Department's commercial investment strategies.[35]

2. The DoD should initiate extensive education and training in commercial leveraging. We have discussed some of the new skills needed to effectively plan, conduct, and transition the output of commercial leveraging efforts. A DoD education and training program should include government science and technology and contracting personnel,

[35] This could be the "second edition" of the report: *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technologies,* OSD, 1994.

as well as industrial representatives at all levels. One role of this training would be to act as a mechanism for sharing lessons learned as new approaches are developed by individual Services. A critical benefit, to be achieved through outreach to industry, could be to encourage commercial industry to suggest government/industry partnerships in their areas, increasing the number of commercial leveraging opportunities to the DoD.

Course development to expand the scope of the DoD program manager is particularly important. Although the Defense Acquisition University provides a critical grounding in military procurement, few courses are offered to the aspiring R&D program manager. And this curriculum is especially deficient in dual use management courses. Some education needs encountered during this study include:

- Basic R&D business knowledge. A project manager must understand the world from the perspective of his counterpart in the business world. Perhaps a series of courses in a conventional business school would suffice.
- Technology search techniques. It is no longer sufficient for military science and technology personnel to understand the technical aspects of his field. They must also know who is likely to be the source of the next advancement or the producer of the next clever application. The successful dual use project begins with a search for new or better technologies and a good way to acquire or develop them.
- Creating the project. Along with understanding the technology and application, creating and negotiating technology development and procurement projects with commercial industry requires a broad understanding of cost sharing, consortia, agreements, foreign participation and other aspects of dual use project approaches.
- Initiating partnerships. Consortia were a major success in the TRP, but it is still new territory for most of U.S. industry, and certainly for government participants.
- Developing and maintaining transition strategies and plans. A critical part of any acquisition project is transition. Part of the training would be to teach the development and conduct of transition strategies and plans that maximize chances of insertion.
- Making tradeoffs between commercial and military design features, producibility, and cost. These tradeoffs occurred throughout the TRP projects. Knowing how to balance commercial and military market goals is crucial.
- Conducting programs. There are significantly different techniques to be applied to the day-to-day management of commercial leveraging projects, with a diverse set of management tools to be applied.

- Evaluating dual use technologies and products. Testing and evaluation of the product concept, prototype, and production configuration must be done in their military context by laboratory and troop testing, and cost/benefit analyses. Acceptance procedures are as important for dual use products as for those delivered through conventional acquisition processes.

3. The DoD should create an acquisition system that maximizes commercial leveraging and transition throughout the Department. The TRP and DUS&T programs encountered many of the decisions expected in a normal acquisition process. But, some aspects of the development-through-procurement process were not experienced fully. These additional facets can be important in enabling DoD to take full advantage of commercial leveraging. For example, the full spectrum of "make or buy" options for needed products and technologies were not considered because all funding was dedicated to dual use (technology co-development). At the other end of the acquisition process are the steps needed to ensure that products delivered through dual use projects are accessible for purchase by the government. For instance, procedures for accepting dual use product concepts, and prototypes, as well as for lot acceptance in dual-production or COTS mode need thought. Finally, a continued effort to improve commercial leveraging program management techniques, while sharing the innovations across DoD, will benefit all Services.

4. Working-level incentives for commercial leveraging should be introduced. The advantages of commercial leveraging are sufficiently well understood at the upper-levels of the DoD to ensure its continuation. But, we found few career or program incentives for the project manager or his customer to compensate for the extra risks and effort entailed in choosing the commercial leveraging route to technology development. This is a serious misalignment that should be addressed.

B. Commercial leveraging programs should implement the management practices that worked for the TRP, while identifying and adopting new innovations. OSD is certainly taking advantage of the management techniques pioneered by DARPA under the TRP. But innovations will also emerge from these DUS&T, COSSI, and other new programs, because they will be managed by a different set of people and because the Service environment is different from DARPA's. Some management approaches that were suggested by our look at the TRP follow:

1. Employ Integrated Product Teams (IPT) in commercial leveraging. The best TRP projects resulted from industry and government people who recognized an opportunity for mutual benefit and worked out a way to take advantage of it. Recognizing and exploiting those opportunities usually demanded a broad perspective on business and

military operational needs, and the technical know-how to meet them. An IPT approach can provide those broad perspectives and seems appropriate for all phases of a commercial leveraging program, starting with the search for new technologies, applications, and better deals. The team approach would also serve in making the initial acquisition decisions, conducting solicitations, negotiating and conducting development projects and, finally, ensuring product insertion into military systems. As appropriate, the military user, project manager, the office managing the system expected to receive the component or technology, and whoever is guiding the end product's commercial strategy may be considered for IPT membership.

2. A transition strategy should always be maintained as part of the project. The transition of TRP products were too often hampered by a lack of emphasis and planning. A transition strategy and plan, updated when circumstances warrant, should always be part of the project. The customer should agree to the strategy. Goals should be identified, along with essential military characteristics that should not be traded off to meet commercial goals.

The government should also stay with a project that shows potential for defense use, even after government funding is over. To avoid "walking off the field at harvest time" should be an important part of the transition strategy.

3. An assessment process should be initiated for all commercial leveraging projects. For reasons given earlier, the adoption of an assessment plan for commercial leveraging projects and programs would enhance their benefits considerably. The assessment process should be initiated early, with goals, performance metrics, and cost metrics established.

4. Strengthen the role of government project managers. The most successful TRP project managers were those who felt they could make critical decisions, stretching their flexibility to the extent that innovative agreements allowed. In fact, both government and industry project managers must be able to make individual product tradeoffs and longer-term commitments based on evaluations of benefits to defense. Each commercial leveraging project is an important investment, which may pay off in ways much different than originally planned. This is due to technical risk, government constraints, and changes in both commercial and military markets. The combination of all of these and other concerns, along with the need to ensure a balance between commercial and military demands, calls for new project manager skills. We found many instances where an empowered TRP project manager made the difference between success and failure.

Annex A. List of Common Acronyms and Definitions

3D	Three Dimensional
3DP	Three Dimensional Printing
AATC	Advanced Automatic Train Control
ABS	Anti-lock Braking System
ACAS	Automotive Collision Avoidance System
ACE	Advanced Communications Engine
ACP	Affordable Composites for Propulsion
ACTD	Advanced Concept Technology Demonstration
ADIO	Analog/Digital/Input/Output
AIM	Aluminum Nitride
ALARA	As-Low-As-Reasonably-Achievable
ALG	Autonomous Landing Guidance
AMEL	Active-matrix electroluminescent
APCS	Air Pollution Control System
ARDEC	Army Research, Development and Engineering Command
ARL	Army Research Lab
ASEP	Abrams System Enhancement Program
ASIC	Application Specific Integrated Circuits
ASPA	Advanced Solid Propellant Armament
ATM	Asynchronous Transfer Mode
ATP	DoC's Advanced Technology Program
ATPA	Active Transmit Phases Arrays
BAA	Broad Agency Announcement
BART	Bay Area Rapid Transit
BGA	Ball Grid Array
BUMED	Bureau of Medicine
BWA	Biological Warfare Agent
C^4I	Command, Control, Communication and Computer Information
CAAA	Clean Air Act Amendments
CAD	Computer-Aided Design
CAEM	Computer-Aided Earth Moving
CAI	Computer-Assisted Instruction
CBBs	Common Building Block Electronic Modules
CCD	Charged Couple Device
CDP	Charge-Domain Processing
CECOM	Army's Communications Electronics Command
CEM	Continuous Emission Monitor
CHPS	Combat Hybrid Power System
CNC	Computerized Numerical Control
CoE	Army Corps of Engineers
COM	University of Rochester's Center for Optics Manufacturing
CORBA	Common Object Request Broker Architecture
COSSI	Commercial Operations and Support Savings Initiative
COTR	Contracting Office's Technical Representatives
COTS	Commercial-off-the-shelf
CPFF	Cost-plus-fixed-fee
CRADA	Cooperative Research and Development Agreement
CTIP	Commercial Technology Insertion Program
CWA	Chemical Warfare Agent
DARPA	Defense Advanced Research Projects Agency

DASHR	Development of Applications Software Hierarchy for Reuse
DATS	Diver Alert and Tracking System
DECT	Digital European Cordless Telephone
DISA	Defense Information Systems Agency
DoC	Department of Commerce
DoD	Department of Defense
DoE	Department of Energy
DOI	Department of Labor
DoT	Department of Transportation
DP	Differential Positioning
DPI	Danish Product Idea
DSB	Direct Broadcast Satellite
DSP	Developing Speech Recognition
DSP	Digital Signal Processor
DTCC	Defense Technology Conversion Council
DUAP	Dual Use Applications Program
DUETS	Demonstration of Universal Electric Transportation Subsystems
DUS&T	Dual Use Science and Technology Program
EACS	Electric Actuation and Control System
EBCCD	Electron Bombarded Charged Couple Device
EL	ElectroLuminesence
EME	Electromagnetic Environment
EMS	Emergency Medical Services
EOE Foundation	Education Object Economy Foundation
EPLRS	Enhanced Position Location Reporting System
EVS	Enhanced Vision Systems
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
FAR	Federal Acquisition Regulations
FBI	Federal Bureau of Investigation
FBL	Fly-by-light
FBW	Fly-by-wire
FCA	Flip-chip Attachment
FCC	Federal Communications Commission
FDA	Federal Drug Administration
FED	Field-Emission Displays
FFP	Firm-Fixed-Price
FID	Flame-Ionization Detectors
FLASH	Fly-By-Light Advanced Systems Hardware
FLIR	Forward-looking infrared
FOG	Fiber Optic Gyro
FPA	Focal Plane Array
FTIR	Fourier Transform Infrared
FTTH	Fiber-to-the-Home
FY	Fiscal Year
GA	General Atomics
Gb/s	Gigabits per second
GBS	Global Broadcast System
GE	General Electric
GHz	Gigahertz
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRIS	Gamma Ray Imaging System
GSM	General Surface Module

GTO	Gate Turn-off Thyristors
GTS	Guided Therapy Systems
HBT	Heterojunction Bipolar Transistor
HDMP	High Density Microwave Packaging
HDPD	High Propulsion Development Program
HIMEMS	High Aspect Ratio Micro-electromechanical System
HITEMP	High Temperature
HMD	Head-mounted Display
HSCT	High Speed Commercial Transport
HTS	High Temperature Superconductor
HyTOP	Hybrid Technology Option Projects
IBM	International Business Machines Corporation
ICs	Integrated Circuit
IDECM	Integrated Defensive Electronic Countermeasures
IMP	Integral Motor/Propulsion
INEEL	Idaho National Engineering and Environmental Laboratory
IOEM	Integrated Opto-Electronic Modules
IPR	Intellectual Property Rights
IPT	Integrated Product Teams
IR	Infrared
IRST	Infrared Seek-and-Track
IS	Information Systems
IT	Information Technology
IU	Image Understanding
JAST	Joint Advanced Strikefighter
JDUPO	Joint Dual Use Program Office
JITC	Joint Interoperability Test Center
JSF	Joint Strike Fighter
LANL	Los Alamos National Laboratory
LCC	Life Cycle Cost
LIDAR	Laser/Light Detection and Ranging
LIS	Laser Ignited System
LOCUSP	Low-Cost Uncooled Sensor Program
LSCAD	Lightweight Stand-off Chemical Agent Detector
LTCC	Low Temperature Co-Fired Ceramic
LTS	Limb Trauma Simulation
LVDT	Linear Variable Differential Transducer
L WiHP	Laser Wind and Hazard Profiler
MAFET	Microwave Analog Front End Technology
MALD	Miniature Air-Launched Decoy
MAN	Metropolitan Area Network
Mb/s	Million bits per second
MBE	Molecular Beam Epitaxy
MCM	Multi-chip Module
MCM E/F	MCM Encapsulated Flex
MCM-L	MCM Laminate
MCNC	Microelectronics Center of North Carolina
MEMS	Micro-electromechanical Systems
MEOM	Micro-opto-eletrcomechanical
MET	Manufacturing Education and Training
MHz	Megahertz
MIT	Massachusetts Institute of Technology
MLAS	Multi Link Antenna System
MMAS	Martin Marietta Armament Systems

MMIC	Monolithic Microwave Integrated Circuit
MMS	Multimedia System
MMW	Millimeter Wave
MO-CVD	Metal-Organic Chemical Vapor Deposition
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NDE	Non-destruction evaluation
NDI	Non-developmental Items
NEST	Nuclear Emergency Search Team
NICd	Nickel Cadmium
NII-HIN	National Information Infrastructure - Health Information Network
NIIIP	National Industrial Information Infrastructure Protocols
NIST	National Institute of Standards and Technology
NSA	National Security Agency
NSF	National Science Foundation
NSWC	Naval Surface Weapons Center
O&S	Operations and Support
O&S	Operations and Support
ODDRE	Office of the Director of Defense Research and Engineering
OEM	Opto-electronic Module
ONR	Office of Naval Research
OOW	Operations Other Than War
OSD	Office of the Secretary of Defense
OTA	Other Transaction Authority
PACS	Pictorial Archiving Communications System
PC	Personal Computer
PCS	Personal Communications System
PDA	Personal Digital Assistance
PHM	Prognostic Health Monitoring
PIP	Program Information Pamphlet
PIPS	Potomac Institute for Policy Studies
PLM	Precision Laser Machining
PM	Program Manager or Project Manager
PMMW	Passive Millimeter Wave
PVDF	Polyvinylidene Fluoride
PWB	Printed Wiring Board
QRSLT	Quick Reaction Spoken Language Translator
R&D	Research and Development
RF	Radio Frequency
RIE	Reactive Ion Etching
RMM	Remote Molecular Monitor
ROI	Return On Investment
ROST	Rapid Optical Screening Tool
RPC	Rochester Photonics Corporation
RTIS	Raytheon TI Systems
RTM	Resin Transfer Molding
SAIC	Science Applications International Corporation
SAIP	Semi-Automated IMINT Processing
SAR	Synthetic Aperture Radar
SBIR	Small Business Innovative Research
SECDEF	Secretary of Defense
SiC	Silicon Carbide
SINCGARS	Single Channel Ground and Air Radio System

SMARTS	Self Monitoring Advanced Remote Technology System
SMES	Superconducting Magnetic Energy Storage
SMTD	Submarine Torpedo Defense
SOCOM	Special Operations Command
SOF	Special Operations Forces
SOI	Silicon-on-Insulator
SOMTC	Special Operations Medical Training Center
SONET	Synchronous Optical Network
SOW	Statement of Work
SPARS	Shipbuilding Partners And Suppliers
SRAM	Static Random Access Memory
SSN	Attack Submarines
SSOG	Solid State Oxygen Generator
STI	Superconductor Technologies, Inc.
STTR	Small Business Technology Transfer
SUO	Small Unit Operations
SVS	Synthetic Vision Systems
SW	Software
SWARM	Shallow Water Autonomous Robotic Minehunting
SWATH	Small Waterplane Area Twin Hull
TAB	Technical Advisory Board
TACOM	Army Tank Automotive Command
TASS	Terminal Area Surveillance System
TC/VRT	Thermocouple/Variable Differential Transducer
TCIMS	Trauma Care Information Management System
TDD	Task Description Document
TI	Texas Instruments
TFEL	Thin-Film ElectroLuminescent
TQM	Total Quality Management
T/R	Transmitter/Receiver
TRP	Technology Reinvestment Project
TWIS	Through-the-Wall Imaging System
TWS	Thermal Weapons Sights
TWT	Traveling Wave Tube
UAV	Unmanned Aerial Vehicles
UCAV	Unmanned Combat Air Vehicle
UCIC	Ultra Clean International Corporation
UCSD	University of California, San Diego
UFP	Unit Flyaway Price
UGS	Unattended Ground Sensors
UML	Unified Modeling Language
UN	United Nations
U.S.	Unites States of America
USA	United States Army
USAF	United States Air Force
USAT	Ultra Small Aperture Terminal
USMC	United States Marine Corps
USN	United States Navy
UTP	Uniphase Telecomm Products
UTRC	United Technologies Research Center
UV	Ultraviolet
UV DIAL	Ultraviolet Differential Absorption
UXO	Unexploded Ordnance
VDVP	Variable Displacement Vane Pump

VE	Virtual Enterprise
VIP	Varian Imaging Products
VIS-W	Vehicular Intercommunications System - Wireless
VITAL	Vehicle Management System Integration Technology for Affordable Life Cycle Cost
VOC	Volatile Organic Compound
VMS	Vehicle Management System
WAN	Wide Area Network
WEMD	Westinghouse's Electro-Mechanical Division
WES	Waterways Experiment System

Annex B. A Brief History of the TRP

I. Introduction

The TRP was in a state of change from its inception. Each competition brought about new procedures and revised instructions to participants. Some of this was due to lessons learned by the TRP in the early competitions and subsequent attempts to correct problems or to enhance the program. Other changes were the result of congressional direction. An example of this was the funding statutes. At the beginning of the Program there were eight statutory divisions of funding,[36] four of which funded development projects. Table B.1. shows the distribution of winning projects between the development statutes by competition.

The Commercial-Military Integration Partnerships statute required at least 50% non-DoD funding in the first year, 60% in the second year, and 70% in the third and later years. The Regional Technology Alliances Assistance statue required at least 50% non-DoD funding in each year. The Defense Dual Use Critical Technology Partnerships and Defense Advanced Manufacturing Technology Partnerships each required at least 50% non-Federal funding in each year. By the third Competition, statutory funding was available only under the Defense Dual Use Critical Technology Partnerships.

TABLE B.1. STATUTORY REQUIREMENTS

DISTRIBUTION OF PROJECTS BY STATUTORY REQUIREMENTS				
Program Element 0603570E	FY 1993	FY 1994	FY 1995	TOTALs
Defense Dual-Use Critical Technology Partnerships	34	14	34	82
Commercial-Military Integration Partnerships	15	11	0	26
Regional Technology Alliances Assistance Program	15	0	0	15
Defense Advanced Manufacturing Technology Partnerships	5	5	0	10
	69	30	34	133

II. The TRP Way of Doing Business

The TRP, managed by only five full time DARPA staff and a Director (who was also Director of DARPA's Defense Sciences Office), gave the impression of a lean organization not burdened by a large permanent bureaucracy. However, at the height of TRP activity (1993-1995) more than 400 people were needed in various support capacities. The immediate support staff consisted of the Working Group and a government contractor who provided administrative support by manning the 1-800-DUAL-USE lines, mailing brochures, receiving, logging, and filing the proposals, typing letters, and providing database support.

Although office space was provided on-site for the Working Group, the members were present on a part-time basis. Most of the Working Group members maintained their

[36] See Title IV, the Fiscal Year 1993 Defense Appropriation Act.

regular full-time positions and considered the TRP work as temporary additional duty. They helped select the technical focus topics, write the Proposal Information Packages, publicize the competitions by traveling the "road shows", answer correspondence and phone calls, and other tasks.

The third competition stressed more military involvement in the process and featured a more direct military relevancy. By Congressional direction, the topic areas were selected by the Military Departments to represent their most compelling needs or interests. The military services were also heavily involved in the selection process. It was mandated that the military make up at least 51% of each selection panel. By executing technology development projects through the military services, the TRP built a cadre of service people who understand how to leverage commercial R&D for military benefit.

In addition, there were several hundred DARPA and Agent technical and contracting support personnel who served as proposal evaluators, contracting officers, and program managers for the three technical areas. Also available to TRP were the part-time services of four legal staff personnel.

Some of the approaches taken by the TRP Management Office to meet the special needs of this program are summarized in the next few sections.

A. Outreach

With much help from their support contingent, the TRP Management Office was able to reach outside the traditional defense research community and communicate with many organizations and individuals through a wide variety of mechanisms. To promote and explain the TRP concepts, "road shows" prefaced each competition. The presentations at these road shows were aimed at providing sufficient information to allow any company the opportunity to understand the process behind the TRP and be able to propose to the program. Copies of the Program Information Package (PIP), a comprehensive brochure detailing all facets of the TRP program were distributed to all in attendance. Following the formal presentations, informal sessions were offered where the Working Group members would meet with individuals to answer any remaining questions particular to their situation.

Additional outreach activities included the 1-800-DUAL-USE telephone line and the TRP World Wide Web site. The 1-800 telephone line was manned 12 hours a day by trained operators. During 1993, 35,827 calls were logged and in 1994 there were 33,736 calls made. In calendar year 1995 there was a significant decrease in calls - to 5,290. However, this could be attributed partially to the fact that the Web site had an average of 16,000 hits per month during that same period. The Web contained all presentation and solicitation documentation, a schedule of events, and an up-to-date list of points of contact as well as supporting documentation, such as, congressional language affecting the program.

Prior to the first competition, over 4,600 individuals attended presentations during April 1993 in New York, Detroit, Orlando, Dallas, and Los Angeles. The second competition outreach meetings were handled a little differently. Seven meetings, designed to focus on the seven selected topic areas, were held during May, 1994. Instead of going around the country, the general public was invited to attend the meetings held in Northern Virginia and Denver. In addition to a Commerce Business Daily (CBD) announcement and Web Page advertisement, invitations were mailed to those organizations or individuals who had attended the first "road shows" and to any individual who had requested such information through the 1-800 phone line. More than 3,000 individuals attended the presentations for the second competition.

In November 1994, to kick off the third competition, the TRP Working Group traveled to Boston, Denver, Seattle, Oakland, Philadelphia, Chicago, Austin, and Atlanta. Due to a number of factors, a much smaller crowd of only 1,800 attended these "road shows." Many interested proposers had already attended previous road shows and were familiar with the TRP process, the topic areas were becoming more focused, the Deployment and MET technical areas had been phased out, and the future funding of the TRP was questionable. Congress had begun to push for a different kind of dual use program and companies were aware of this.

In addition to outreach activities aimed at the public, seminars were held for government personnel. These meetings occurred in July and August 1994. Program managers and contracting officers from the first competition, just completed, and the second competition, now underway, were invited. Lessons learned were related by many attendees and a number of interface problems and issues were discussed. Relationships and roles of DARPA, TRP, other agencies, and the TRP consortia were discussed. A major acknowledgment was the compelling need for more and better communication among all members throughout the entire process, from selection of topic areas through negotiations of the agreements. A direct result of these seminars included early kick-off meetings for each partnership, thus allowing a better working relationship between the government and partners.

B. Announcements

Even though the TRP was conducted outside the FAR, by law every TRP project had to be selected solely on its merits through a fair and open competition. The TRP adhered to this requirement rigorously and believed it absolutely crucial to the quality and credibility of the program. Every TRP project was selected without regard to geographic location or any factor other than the published criteria.

There were three solicitations/competitions with subsequent announcements of winners (see Table B.2.). However, due to congressional language which initially called for specific set asides, the first competition actually had three separate announcement dates for the development projects - the first being October 22, 1993. This announcement was made by President Clinton at the White House. The final Technology Development

announcements for this initial competition were on November 24, 1993 and February 23, 1994.

TABLE B.2. TIME TABLE OF SIGNIFICANT COMPETITION EVENTS

Competition	Program Begins	PIP Published	Concept Papers Due	Outreach	Solicitation Published	Proposals Due	Evaluations Completed	Announcements
First	Dec 16, 1992	Mar 10, 1993	N/A	Apr 1993	May 14, 1993	Jul 23, 1993	Sep 28, 1993	Oct 22, 1993
Second	Dec 14, 1993	Apr 1994	N/A	May 1994	May 20, 1994	Jun 30, 1994	Sep 20, 1994	Oct 21, 1994
Third	Jan 4, 1994	Nov 7, 1994	Dec 21, 994	Nov 1994	May 12, 1995	Jun 29, 1995	Nov 8, 1994	Dec 21, 1995

* See announcements paragraphs below

As Table B.2 indicates, although TRP employed unique and innovative efforts and concepts, its solicitation process was ultimately no faster than the traditional competitive solicitation and perhaps in some areas, even slower. Based on published dates, it's clear events in the first and second competitions took about the same amount of time. The third competition, however, was a little slower in implementation. Though an extra event, the Concept Paper process, was introduced in the third competition, that in itself did not cause undue delays. Most delays were the result of outside forces and not within the control of the TRP. Many decisions and the announcement were held pending the uncertain outcome of future funding. Once the defense appropriations bill had been passed, and a line item identified for TRP, the program could continue with the competition as had been planned. However, by this time, the schedule was three to fours months late.

C. Source Selection

All winning projects were selected using a rigorous, multi-tiered Source Selection Process. This process was designed to prevent outside influence and ensure that the best proposals prevailed.

Several evaluation requirements were mandated by Congress. These included partnerships, private sector cost sharing, technical excellence, and defense relevance. Congress also required that several groups should be beneficiaries of the program; small and defense-dependent businesses; historical black colleges and universities; minority institutions; and state and local organizations that were assisting in defense conversion efforts.

The second competition selection process is used as the example of how all the competitions were run (with only minor changes in each). Evaluation teams were comprised of technology experts from the Department of Defense and the other five federal agencies participating in the TRP [Commerce (NIST), Energy, Transportation, NASA and NSF]. Every evaluator signed a Conflict of Interest Statement and an Unauthorized Disclosure of Information Agreement. Evaluators were prohibited from discussing proposals or their status outside the selection process.

The TRP solicited proposals in specific technology focus areas. For each area, DARPA established a Focus Area Evaluation Committee, composed of a DARPA Chair and

technical experts from DoD and the other Agencies. TRP assigned each proposal to the appropriate Focus Area Evaluation Committee.

Proposals were rated by individual evaluators in the appropriate Focus Area Evaluation Committee. Evaluators used only the criteria published in the TRP solicitation. After the individual ratings, members of each Evaluation Committee met to discuss the proposals and each proposal was given a consensus score and rank. Individual evaluators were permitted to submit a "minority report" if they disagreed with the consensus of the Committee. As an additional step, the Committee was allowed to seek clarifications to proposals. No changes to a proposal were allowed as part of any clarification. Based on all of this information, proposals were assigned a final rating by the Focus Area Evaluation Committee; the highest ranked proposals were forwarded to the Technology Development Panel.

The Technology Development Panel was chaired by DARPA and was composed of representatives from DoD and each of the other five participating agencies. There was no overlap between members of the Technology Development Panel and the Focus Area Evaluation Committees. The Focus Area Evaluation Committees presented their highest ranked proposals to the Technology Development Panel and panel members ranked proposals across focus areas. The Technology Development Panel then forwarded its recommendations, consistent with program budget limits, to the Defense Technology Conversion Council (DTCC) Working Group.

The DTCC Working Group, chaired by DoD, with representation from the participating agencies, reviewed the recommendations of the Technology Development Panel to ensure quality and consistency. Finally, the recommendations of the Working Group were presented to the DTCC itself, which was chaired by the Director of DARPA. Because TRP funding was appropriated to DARPA, that Agency retained the final Source Selection Authority.

The source selection process remained fairly constant throughout the three competitions. However, for the Third Competition, Congress mandated that the military representatives make up the majority of members on the Source Selection Evaluation Board (what had been called the Focus Area Selection Committee). The TRP went to great lengths to ensure that this mandate was carried out. The SSEBs recommendations were forwarded to the Technology Evaluation Panel (formerly the DTCC Working Group) with final review and approval by the Source Selection Authority.

Prior to the third competition, TRP adopted the concept paper process as an additional way of providing guidance and direction for the proposers. It was directed at giving feedback on ideas before a full proposal was written, partly to alert people that their proposals might have inadequate defense benefits. Interested teams were strongly encouraged to submit a five page concept paper before investing time and effort in the development of a full proposal. Submitters of concept papers could use feedback from this process to make their own decision on whether to prepare a full proposal. It was TRP's goal in using concept papers to discourage full proposals from submitters whose proposal concept would have a low probability of being funded by the TRP and to

provide constructive feedback to those proposers whose ideas had a better likelihood of success. The concept paper evaluation team had many of the same members who evaluated the final proposals. The same confidentiality rules applied for evaluation of the concept paper as it had for the final solicitation. TRP feedback to submitters was in the form of a qualitative rating of the concept paper for each criteria. It also included the number of concept papers submitted in that particular focus area and guidance to assist proposers in the decision about submitting a full proposal.

A number of Topic Areas were eliminated between the concept paper evaluation process and the actual solicitation. For the third competition, Congress had directed that the Army, Navy, and Air Force to each propose at least two topic areas of special interest. Those areas eliminated were determined by the Departments to be their lowest priority. In addition, Congress did not appropriate funds in the Regional Technology Alliance Assistance statute and that area was also eliminated.

Depicted in Table A.3. is a compilation by topic area of the number of proposals received and selected during each of the three competitions. Note that the third competition had the additional "concept papers" process.

TABLE A.3. NUMBER OF PROPOSALS RECEIVED/SELECTED BY TOPIC AREA

First Competition - 1993

Proposals Received	Topic Area	Selected	$M Gov't Amt
272	Information Infrastructure	11	$87.6
171	Electronics Design and Manufacturing	9	$43.6
124	Mechanical Design and Manufacturing	3	$21.6
214	Materials/Structures Manufacturing	3	$36.8
216	Health Care Technology	9	$23.1
58	Training/Instruction Technology	1	$3.0
204	Environment Technology	6	$7.1
112	Aeronautical Technologies	7	$35.2
261	Vehicle Technology	5	$25.5
76	Shipbuilding Industrial Infrastructure	5	$16.7
26	Advanced Battery Technology	3	$8.3
93	Other	7	$19.1
1827	**Totals**	**69**	**$327.6**

Selection Rate = 3.8%

Second Competition - 1994

Proposals Received	Topic Area	Selected	$M Gov't Amt
13	High Density Data Storage Systems	2	$16.0
10	Object Technology for Rapid Software Development and Delivery	3	$19.5
38	Interoperability Testbeds for the National Information Infrastructure (NII)	5	$23.2
24	High Definition Systems Manufacturing	3	$48.3
40	Low Cost Electronic Packaging	9	$38.3
8	Uncooled Infrared Sensors	3	$21.6
32	Environmental Sensors	5	$9.5
3	Other	0	$0
168	**Totals***	**30**	**$176.4**

Selection Rate = 17.8%

* Although 30 proposals were selected, only 28 reached agreement. Dollar value shown reflects amount that had been set aside to fund the 30 proposals. $10M fro High Density Data Storage Systems and $4.5M from Interoperability Testbeds for NII was redirected to the next competition.

Third Competition - 1995

Concept Papers Received	Proposals Received	Topic Area	Selected	$M Gov't Amt
134	28	Biological Sensors and Multiorgan Diagnostic Screening	5	$15.0
21	1	Affordable Polymer Matrix Composites for Airframe Structures	0	$0
68	22	Affordable Advanced Controls Technology	6	$42.5
77	20	Digital Wireless Communications and Networking Systems	6	$23.4
175	33	Operations Other Than War/Law Enforcement (OOTW/LE)	6	$21.0
46	7	Small Precision Optics Manufacturing Technology	4	$12.8
35	8	Microelectromechanical Systems (MEMS) Applications	2	$7.8
178	24	Other	5	$16.8
734	**143**	**Totals**	**34**	**$139.3**

Selection Rate = 23.8%

Concept Paper Data

Areas Eliminated Prior to Request For Proposals

Concept Papers Received	Topic Area
31	Ceramic Material Applications: High Performance Ceramics
23	Cryogenic Coolers for Electronic System Applications
63	Electric and Hybrid Tactical and Commercial Vehicles
65	Low Cost Specialty Metals Processing
33	Millimeter Wave Products for Military and Civilian Applications
215	Number received under the eliminated areas
137	Number received under RTA funding - also eliminated
70	Number received but not reviewed (MET or Deployment)
422	Total number received for non-funded or not reviewed areas
734	Total number received for funded Topic Areas
1156	**Total Concept Papers Received for Third Competition**

"Gov't Amt" is the amount of funding TRP had available prior to each competition. Final negotiated amounts varied slightly.

D. Innovative Agreements

The TRP was conducted outside the FAR. TRP projects were investment partnerships in the interest of all the parties; they were not procurements. A TRP relationship required more flexibility than a typical federal contract, which assumes a buyer-seller relationship. FAR procedures would have been both inappropriate and too rigid for the TRP. Although most of the non-DoD agencies and the DoD Military Services had authority to use the Other Transaction Agreement, only DARPA aggressively employed them. The other agencies and DoD Military Services primarily relied on the Cooperative Agreement as specified in the FAR.

At the end of the second competition there were 97 signed agreements in place. Of those, 57% had been negotiated under a Cooperative Agreement and 38% under the Other Transactions authority. The other 5% consisted of grants, NASA's Space Agreements, and other similar contracting vehicles. The mix of document type, however, had now changed. The Services had taken over as the negotiation lead on all but one of the 34 selected proposals. But, they began to use Other Transactions

Agreements, changing the percentages between Cooperative Agreement and Other Transactions to 48% and 43%, respectively.

In order to provide a distinction between the two major types of contracting vehicles used to negotiate the TRP partnership agreements, the following definitions were excerpted from a TRP Program Information Pamphlet (PIP).

"Cooperative Agreements are used when the purpose of an agreement is to transfer something of value to the recipient to support and stimulate R&D for some public purpose. Government funding is more in the nature of an investment in such situations than a purchase. Procurement contract regulations generally do not apply, so there is flexibility about such things as intellectual property rights."

"Other Transactions are just that - any form of transaction that is not a grant, contract, or cooperative agreement. These may include (but are not limited to) loan agreements, coordinated research, consortia, joint funding arrangements, and reimbursable arrangements. Such agreements can be structured with great flexibility to meet the needs of the participants and the government in each particular situation."

The TRP worked to create an environment that encouraged people to learn new methods. In this way, the TRP became a catalyst for fundamental changes in the R&D methods used by all DoD Military Services and Agencies. Two examples of advantages in using the Other Transactions are:

(1) Property Rights - Other Transactions allow disposition of rights in inventions to be structured through negotiations so as to best serve national security objectives of Section 2501, Title 10, United States Code.

(2) Intellectual Property Rights - "Treatment of intellectual property issues shall be extremely flexible, with due consideration given to the underlying purposes of the programs, particularly, the national security objectives under Section 2501, Title 10, United States Code."

E. Cost Sharing

Cost sharing was used to ensure that TRP consortia are committed to their projects and believe that the technology is commercially viable. It also encourages efficient and diligent project management. The TRP paid no more than half the cost of any project. In fact, over 60 of the winning consortia contributed more than 50 percent even though not mandated to do so. Sharing the cost made each project a risk-sharing investment of interest to all the parties, not a sale to the government.

Partner cash contributions took a number of forms. Considered acceptable were: (1) contributions from project participants and third parties, including states, counties, cities, companies, or other sources; (2) revenues from license fees and royalties; and (3) fees for services performed.

In addition, in-kind contributions were acceptable in some cases. They included (1) compensated services of full-time and part-time personnel; (2) in-kind value of equipment (including software) necessary and reasonable for proper and efficient accomplishment of project objectives; and (3) in-kind value of land, buildings, or space, necessary and reasonable for proper and efficient accomplishment of proper objectives. The PIP described in detail how a proposer could apply his cash and in-kind contributions. Out of the first two competitions, approximately 22 funding agreements included in-kind contributions. The exact number is difficult to identify due to the various methods that the individual contracting officers used to present this information. Dollar value for the combined contributions is also very difficult to identify. There was no agreed-upon algorithm. Each company brought its own unique contribution to the partnership and the total value cited depended on a lot of variables. This information is incomplete for the third competition.

The majority of the partnerships (64%) planned for a 24 month base period of performance, the shortest period being 12 months and the longest 36 months. Several agreements did identify optional work. All options had the same cost sharing requirements as the base efforts and had to compete for available dollars. The TRP Working Group selected options primarily on the merit of the base program, but also keeping in mind the constraints of available funding.

To give a general idea of the dollar size of the negotiated agreements, the total amount of the base agreements was divided into three levels. There were 47 projects under $4 million; 45 projects between $4 million and $10 million; and 41 projects fell into the category over $10 million. These levels have been based on the TRP share times 2 (assumes at least 50% cost share).

Annex C. Military Need Categories

Seven areas of military need were addressed by TRP projects. Those categories are summarized below, with a listing of projects associated with each. In some cases there are TRP strategies defined for a sub-area of need (such as ultrasound imaging devices under Casualty Care).

1. Military Mobility and Deployment: This category of military need focused on the task of bringing commercial technologies to bear on military transportation, in and out of the battle area.

A. Land Vehicles: The DoD has the most complex, if not the largest, fleet of land vehicles in the U.S. Utility, or administrative, vehicles will benefit directly from commercial vehicle technology advancements. By exploiting commercial technologies and influencing commercial developers to address military problems, the TRP tried to seed advancement and affordability in electric and hybrid drive components, land navigation, and safety systems. Tactical and armored combat vehicles have many distinctly military characteristics seldom shared by their civilian cousins, with some exceptions found in the earthmoving, heavy equipment, and rail industries. These special concerns and opportunities were also addressed by TRP projects. Among these are hybrid propulsion, where there are benefits from silent running (stealth), and design flexibilities (allowing better vehicle layout). Further, on-board electric power generation is a growing necessity for propulsion, armament, communications and computation, and protection systems. Some projects in this category are:

- "Power Pak" Mobile Electric Power System
- Demonstration of Universal Electric Transportation Subsystems (DUETS)
- The $2000 Electric Powertrain
- Electric Variable Transmission
- Turboalternator for Electric Hybrid Vehicles
- SiC Power Electronics for Affordable Next Generation Electric and Hybrid Vehicles
- Power Electronic Building Blocks for Affordable High Performance of Electric Power
- Model Based Control and Diagnostics
- Computer-Aided Earth Moving With DP-GPS
- Vehicle Management System Integration Technology for Affordable Life Cycle Cost (VITAL Program)
- Interoperability Testbed For Diagnostic and Prognostic Maintenance of Equipment and Processes
- Low Cost Packaging Technology for Automotive Electronics
- Automotive Micromachined Gyro and Derivative Applications
- Gas Generator Fire Suppression

B. Shipbuilding Technologies: For years, the international commercial shipbuilding market has been out of reach for our shipyards. The U.S. shipbuilding industry has relied heavily on Navy procurements. For example, in Desert Storm, 95% of the logistics necessary for ground operations was shipped through the sea lanes. But, current and projected Navy combatant/auxiliary ship construction is insufficient to maintain the industrial shipbuilding capacity required for mobilization. The TRP sponsored projects intended to assist the U.S. shipyards and related industries to become competitive in international commercial markets and thereby preserve a viable shipbuilding infrastructure for defense. The effort addressed innovative ship design and construction processes and ship systems technologies such as propulsion and auxiliary systems. Projects addressing these concerns were:

- Commercial Shipbuilding Focused Development Project
- Demonstration & Spin-Off of the Integral Motor/Propeller Propulsion System
- Development of the Submerged Electric Drive Cargo Pumping System
- Portable Shipbuilding Robotics
- Center for Advanced Ship Repair and Maintenance
- ISMIS (Intelligent Shock Mitigation and Isolation System) Through Applied RSPM Technology

C. Aircraft Technologies: The United States enjoys a dominant position in the world's aircraft market because of the distinct technological advantage won by an aggressive R&D investment strategy, especially in the defense sector. However, both Europe and Asia are challenging this preeminence. Aeronautical technology dual use investments that were sponsored by TRP include:

- Aircraft Surface Contamination Detection Technology Advancement
- Fly-By-Light Advanced Systems Hardware (FLASH) Program
- Dual Use Sensor Technology for Air Transportation System Capacity and Safety
- Electronically Controlled Variable Displacement Vane Pump
- Autonomous Landing Guidance (ALG)
- Just-In-Time Maintenance
- Advanced CTP800 Turboprop for Surveillance Aircraft
- High Temperature Distributed Control Systems
- Industry Common Building Block Electronic Modules

2. C^4I: The Joint Staff and the Joint Requirements Oversight Council of DoD identified the goal, "To maintain near perfect real-time knowledge of the enemy and communicate that to all forces in near-real time," as the first of five future joint warfighting capabilities most needed by the U.S. Combatant Commands. Near-real time communication requires very high bandwidth communications networks -- something the DoD does not possess. DoD forecasts indicate that capacities of tens to hundreds of terabytes of data per day by the year of 2000 are necessary in order to meet the

increasing needs in intelligence, surveillance, communications, command and control functions. While military needs for secure, digital, networked, high data rate, and updatable systems are well documented, it is not feasible for the Services to develop, produce, and maintain military-only communications equipment. This is due to prohibitive costs and the fact that the most advanced technology is found in the commercial sector. Demands for more frequent upgrades due to the remarkable rate of advancement of this technology area leave little choice but to turn to commercial industries and to ensure that technologies developed in the commercial world are appropriate for military application.

A. Wireless Communications Technologies: Wireless communications is enjoying considerable commercial development at present. The remarkable progress in technology and affordability in the commercial wireless industries pose solutions for the military's dilemma. Without DoD presence, the commercial sector may not produce equipment that meets military requirements for bandwidth, network robustness during movement, resistance the effects of electromagnetic interference and jamming; rapid deployment (fixed baseline infrastructure versus total mobility); and security. There are advocates in the commercial marketplace for solutions to each of these problems, but that advocacy is too small to be addressed unless DoD's commitment to cost share in the development stage and to buy commercial components and systems is evident. The Single Channel Ground and Air Radio System (SINCGARS) required nearly 20 years to field. As a result it was out-of-date when fielded. The DoD cannot allow this to become a precedent of how the military proposes to remain on the "cutting edge of technology." Pertinent TRP projects are listed below:

- Miniature Filters For Wireless Networks
- Advanced Automatic Train Control (AATC) System
- Advanced Communications Engine (ACE)
- Testbed for Digital Wireless Communications and Networking Systems
- Development/Application of Advanced Dual Use Microwave Technologies For Wireless Communications And Sensors For IVHS Vehicles
- Spatial Division Multiple Access Wireless Communication Systems

B. Intelligence and Data Distribution Technologies: The TRP sought many applications of dual use technology to serve intelligence information systems. This included the transmission of sensor data.

- Integrated Opto-Electronic Modules (IOEM)
- Experimental SONET OC-192 (10 Gb/s) and ATM Self-Healing Ring, An
- ATM Interoperability Testbed for the National Information Infrastructure, An
- Manufacturing Process Development for Thin Multi-Layer (Flat Panel) Antennas
- Cryo-Electronics for Microwave Systems
- Short Wavelength Optical Storage
- Quick Reaction Spoken Language Translator (QRSLT)

- High Power High Temperature Superconducting Technology
- Analog Optoelectronic Module Development
- Commercialization of DoD IUA Vision Computer

C. Displays: One of the earliest OSD dual use thrusts was in flat panel displays. The TRP continued this, with projects in TFEL, manufacturing, and application to wearable computers.

- TI/Raytheon 'Leap-Ahead' Approach to U.S. Flat Panel Display Competitiveness - Field Emission Displays
- Next Generation High Resolution & Color TFEL Displays
- Wearable Computer Systems with Transparent, Headmounted Displays For Manufacturing, Maintenance and Training Applications
- Customer Driven FED Manufacturing Partnership

D. Other Computer and Information System Technologies: Some projects in this area were concerned with software development and protocols. We listed these separately below:

- LEGOS: Object-based Software Components for Mission-Critical Systems
- Object Technology for Rapid Software Development and Delivery (now Development of Application Software Hierarchy for Reuse, or DASHR)
- National Industrial Information Infrastructure Protocols (NIIIP)

3. Battlefield Sensors and Optics: Several sensor technologies were developed. Applications include enhanced detection in the visual, IR and RF spectra, and detection of nuclear waste and various forms of pollution.

A. Battlefield Sensors: The most successful of these efforts was the development of uncooled IR technologies. The U.S. military has "owned the night" because of generations of cryogenically-cooled IR sensors. These sensors were a major reason for our ground victory in Desert Storm. Unfortunately, the high cost of cooled sensors has precluded wide distribution to combat troops' for manportable applications. Although the performance of uncooled infrared sensors is below that of the cooled sensors, they are superior (in nearly all circumstances) to light intensification equipment that is today's low-cost alternative. The military procures about 10,000 units per year, but the potential civilian market is around 100,000 units per year. TRP goals were to make better-performing IR systems available to the military at less than one-tenth the cost. The original (pre-TRP) uncooled prototype, the Low-Cost Uncooled Sensor Program (LOCUSP), cost around $30,000. The activities under this focus area improved the sensor technology considerably and reduced the device cost to around $8,000.

Other sensors included radar and cryogenic cooling components. Besides those projects listed below, there were a number of sensors integrated by the TRP into systems covered in other categories of military need, such as Aircraft Technologies and Casualty Care.

- Uncooled Infrared Sensors
- Uncooled IR Microbolometer Sensor Cost Reduction Program
- ULTRA
- Passive Millimeter Wave Camera
- Beam-Agile Active Transmit Phased Array System
- Electron Bombarded CCD Camera
- Laser Wind and Hazard Profiler (LWiHP)

B. Environmental Sensors: The goal of the environmental sensors focus area was to stimulate the development of new field deployable sensor technologies and real-time data processing/storage/transmission systems to detect and monitor a variety of environmental contaminants. Key requirements included chemical specificity, high sensitivity, automatic sampling, real-time data analysis, robust design, compact size, and cost-competitiveness. In commercial and civil roles, these sensor systems are needed for high-resolution site characterization, countering environmental terrorism, and providing immediate feedback for the control of industrial manufacturing processes. Demanding regulatory agency acceptance for all of the devices developed enhanced chances of commercialization. These activities will enable the government to more effectively monitor and identify harmful chemicals and biological organisms at military facilities, to detect biological and chemical warfare agents during combat, and to perform chemical and biological warfare treaty verification.

- Gamma Ray Imaging System for Nuclear Environment Monitor
- Miniaturized Environmental Monitoring Instrumentation Based Upon the Mass Spectrograph Chip
- Air Quality Monitoring System Using a Neural Network Based FTIR Spectrometer
- UV DIAL LIDAR
- E-Smart System for In-Situ Detection of Environmental Contaminants
- IMAS: An Intelligent Modular-Array System for the Monitoring of VOCs in the Environment
- EcoScan - A Tunable IR Laser Remote Sensing System
- Field-Deployable, Continuous Monitoring Mass Spectrometer
- Volatile Organic Compound (VOC) Sensors, Communications, Processing and Display
- Advanced "Zero Emissions" Control Valve Development
- Self Monitoring Advanced Remote Technology System (SMARTS)

C. Optics: Major thrusts of the TRP were to pursue the development of diffractive and aspheric optics.

- Diffractive Optics Technology for Battlefield Management Systems
- Deterministic Design, Manufacture and Assembly of Aspheric Optics
- Integrated Small Precision Optics Manufacturing Technology

- Cost Effective Manufacturing Technology for Fabricating Hybrid Diffractive Optics

4. Casualty Treatment: Studies show that a large number of combat zone casualties must be diagnosed and receive care during the hour after being injured, or their chances of recovery are poor. The percentage of wounded who survive this "Golden Hour" has not changed since the civil war. Major reasons for this is the difficulty of extracting diagnostic information and obtaining expert medical advice under battlefield conditions. The strategy was to enhance both civilian emergency and military combat casualty care through the development of devices for biosensing human physiologic parameters and for organ systems diagnosis, and by applying information management and networking technologies to telemedicine. Sensor suites and information systems aid the diagnosis of injuries, remotely monitor medical status, track diagnoses and treatments, and maintain information about the wounded soldier from the battlefield to the aid station and all the way to hospitals in the U.S.. This provides valuable triage information. The capability for continuous and non-invasive sensing of vital signs and body chemistry to develop remote diagnosis, to virtually place the physician at the side of the wounded soldier, is crucial to save lives in the combat zone.

The DoD benefits, in a number of ways, from commercial involvement and application of these technologies. First, emergency teams and hospitals will work with the emerging products on a daily basis, providing new system data, as well as feedback on design and use, while actual military employment will be confined to training and (hopefully infrequent) conflicts. Secondly, the efficiencies inherent in a large market such as the health care industry will reduce costs of all technologies. Lastly, military medical services will increasingly depend upon the commercial health care system for personnel (e.g., reserve duty, consultants), so it is imperative that DoD casualty treatment systems be compatible and interoperable with commercial systems. Some of the projects are:

- Microfabrication of Ophthalmic Surgical Knives Process Development and Mechanical Design
- Advanced Pictorial Archiving Communications System (PACS)
- National Academic Medical Center Information Collaborative
- Trauma Care Information Management System (TCIMS)
- Portable 3D Imaging Ultrasound Systems Based on 1.5-D and 1-D Integrated Arrays
- Low-Power, High-Resolution, Portable Ultrasound Imaging System
- Virtual Endoscopy
- Combat Surgical Ultrasound System & Probes with Multi-Modality Image Fusion, for Front Line Surgical Guidance & Telesurgery
- Portable Ultrasound Device for Battlefield Trauma
- A System for Noninvasive Arterial Blood Gas Measurement
- Solid State Oxygen Generator (SSOG)
- Surgical Simulation for Limb Trauma Management
- Amorphous Silicon Medical Imager

- Digital X-Ray System for Trauma and Battlefield Applications
- National Information Infrastructure - Health Information Network (NII-HIN)

5. Electronics Design And Manufacturing: Although the military is extremely reliant on advanced electronics, it can no longer count on the defense industry to provide the cutting edge. The global market place has created electronics components and subsystems that are generally more advanced and less expensive than that found in defense products. Yet, as crucial as electronics are to defense, the DoD share of the market is rapidly dwindling. For example, the DoD buys over a billion dollars worth of integrated circuits every year, but the military market is only about 3% of the total market and is declining. The challenge is to leverage the commercial electronics market for advanced technologies and affordability typical of today's commercial industry with size, ruggedness, environmental stability and special functions that are needed for military missions. This was a TRP mission, being pursued in the areas of process control for electronics manufacturing, Multi-Chip Module (MCM) technology and Low Cost electronic packaging, and power storage.

A. Process Control for Electronics Manufacturing: Two projects were examined in this area:

- Extrapolation of Adaptive Optics Technology to the Manufacture of Electronics and Next Generation Information Display Systems
- In-situ Process Control for Growth of InP-Based Heterostructure Materials For Gigahertz Circuits

B. Multi-Chip Module (MCM) technology: One of TRP's focus areas concerned this important area of technology. Under this category, TRP sponsored work in manufacturing, materials, and design.

- Low Cost, High Performance Tooling By Three Dimensional Printing
- The Consortium - The Path to a Globally Competitive MCM Industry in the U.S.
- Low Cost Electronic Packaging Through Systems Approach to Ball Grid Array Package Assembly
- Technology and Productization Acceleration of Low Cost, Aluminum Nitride Electronic Packaging
- Technology to Produce High Performance/Low Cost Interconnections for Flip Chip Attachment
- Low Cost Flip Chip

B. Low Cost Packaging: These projects focused on reducing the cost of electronic packaging in the military systems through the improvement and adoption of commercial packaging processes. The DoD buys over a billion dollars worth of integrated Circuits (IC's) every year for military systems. Military specialized computer parts contain IC's that almost exclusively employ ceramic packaging. Ceramic packaging generally costs five to ten times that of plastic packaging. It is estimated that a shift of half of the DoD

components to plastic would result in a cost savings of about $120M per year on the component level and as much as $400M on the device level. In fact, the DoD must eventually embrace commercial packaging, since the military market comprises only about 3% of the total IC market and is declining.

- Pad Printer
- Low-Cost Plastic Packaging
- Competitive Low-Cost Packaging for Wireless Communications in a Global Market
- Low Cost, High Density, Sequential Build PWB Manufacturing

C. Power Storage: Several projects were dedicated to reduce the extremely grave logistical problem of supplying, carrying, and replacing batteries to feed the growing electronic component of both "tooth" and "tail" operations.

- Advanced Power Conversion Based On the Aerocapacitor
- High Capacity Solid Polymer Battery Development
- Lithium Ion Rechargeable Battery Development and Deployment
- Commercialization Demonstration of Mid-Sized Superconducting Magnetic Energy Storage (SMES) Technology for Electric Utility Applications

6. Mechanical Systems, Materials and Manufacturing: The objective of this category of military need was the design and manufacture of electrical and mechanical systems requiring forming and assembly. Some specific areas for research included the use of advanced information support for design and manufacturing, use of flexible robotic systems, integrating the description of the component/system to be manufactured with the manufacturing process, and selected areas in forming and assembly.

A. Microelectromechanical Systems (MEMS): These two projects attempted to accelerate the affordability, manufacturability and insertion of MEMS devices and systems. Starting from demonstrated MEMS devices and concepts, technology developments focused on specific, dual use products or markets that are driven by device affordability and manufacturability. Manufacturing technologies were pursued that would produce applications to satisfy various civilian and military needs. Applications included embedded pressure sensors for passenger car, truck and aircraft tires, fluid valving, and analytical instruments.

- A Regional Technology Alliance for High Aspect Ratio MEMS Technology Development
- Development of Monolithic Motion-Detecting Components Made with MEMS Technology

B. Materials and Manufacturing: Establishing and maintaining technological leadership in the use of advanced materials and manufacturing is essential to continuing and strengthening the competitiveness of the U.S. aerospace industry and to achieving leap-ahead performance improvements in military aircraft. For example, current use of composite materials in military and commercial transport aircraft in the U.S. has been,

for the most part, limited to secondary structure. The true payoff for use of these materials lies in their application to a primary load bearing structure, such as wing spars, which accounts for the majority of both aircraft weight and airframe structure cost. Successful application of polymer matrix composites to primary structure will improve aircraft energy efficiency and range, and maintain an industrial base in both materials and structures manufacturing, all of which is critical to DoD needs. Application was made to bridge structures, as well. Two projects to develop systems for rockets and missiles were included in this category. Manufacturing projects featured a powerful new manufacturing tool, a bonding technique, and a computer application.

- Affordable Composites for Propulsion
- Advanced Composites for Bridge Infrastructure Renewal
- Dual Use Hydrostatic Bearing Program
- Hybrid Propulsion Development Program (HDPD)
- Precision Laser Machining
- Low Cost Packaging Based on Area Bonding Adhesives with X,Y and Z Axis-Conductivity

7. Weapons, Survivability And Other: Weapons needs common to the commercial and military sectors are rare, but there were two dual use weapon support systems pursued under the TRP. An education technique using the internet was developed for possible application to military training.

- Pyrotechnic Actuated Vehicle Rescue Equipment
- Diver Alert and Tracking System
- HyperEducation Consortium

ANNEX D. Synopses of Case Studies

Table D.1. is a listing of all surveyed TRP Technology projects. Following this table, case studies are synopsized in the same order as they appear in the listing. In the synopses, descriptions of project status are in italics.

TABLE D.1. TRP PROJECTS

PROJECT TITLE	LEAD COMPANY	NR.
$2000 Electric Powertrain	Westinghouse Electric Corporation	1616
Advanced Automatic Train Control (AATC) System	BART	1126
Advanced Communications Engine (ACE)	Hughes Communication Projects	13016
Advanced Composites for Bridge Infrastructure Renewal	University of California, San Diego	1230
Advanced CTP800 Turboprop for Surveillance Aircraft	Allied Signal, Inc. - Engines	14026
Advanced Pictorial Archiving Communications System (PACS)	Lockheed Martin	2576
Advanced Power Conversion Based On the Aerocapacitor	Polystor	1229
Advanced "Zero Emissions" Control Valve Development	Target Rock Corporation	3366
Affordable Composites for Propulsion (ACP)	Pratt & Whitney	1428
Air Quality Monitoring System Using a Neural Network Based FTIR	Spectrometer AIL Systems, Inc.	3275
Aircraft Surface Contamination Detection Technology Advancement	Rosemount Aerospace, Inc.	3512
Amorphous Silicon Medical Image	Ginzton Research Center (Varian Associates)	2518
Analog Optoelectronic Module Development	Hughes Research Laboratories	3541
ATM Interoperability Testbed for the National Information Infrastructure, An	Bellcore	5111
Automotive Collision Avoidance System (ACAS)	Delco Electronics	2430
Automotive Micromachined Gyro and Derivative Applications	Boeing North American	16005
Autonomous Landing Guidance (ALG)	Lear Astronics Corporation	3462
Beam-Agile Active Transmit Phased Array System	Space Systems/Loral	3655
Combat Surgical Ultrasound System & Probes with Multi-Modality Image Fusion, for Front Line Surgical Guidance & Telesurgery	TETRAD Corporation	12005
Commercial Shipbuilding Focused Development Project	Bath Iron Works Corporation	2140
Commercialization Demonstration of Mid-Sized Superconducting Magnetic Energy Storage (SMES) Technology for Electric Utility Applications	BWX Technologies, Inc.	2224
Commercialization of DOD IUA Vision Computer: An Enabling Technology for CAD-Directed Vision-Guided Robotics for Flexible Manufacturing	Amerinex Artificial Intelligence, Inc.	2114
Competitive Low-Cost Packaging for Wireless Communications in a Global Market	National Semiconductor Corporation	5114
Computer-Aided Earth Moving With DP-GPS	Leica	3353
Consortium - The Path to a Globally Competitive MCM Industry in the U.S.	The MCM-D Consortium	3087

Cryo-Electronics for Microwave Systems	Superconductor Technologies, Inc.	17004
Customer Driven FED Manufacturing Partnership	Candescent Technologies Corp.	5051
Demonstration of Universal Electric Transportation Subsystems	NovaBus	2390
Demonstration & Spin-Off of the Integral Motor/Propeller Propulsion System	Westinghouse Electric Corporation	2319
Deterministic Design Manufacture and Assembly of Aspheric Optics	University of Rochester Center for Optics Manufacturing	15003
Development of Application Software Hierarchy for Reuse	Template Software, Inc.	5154
Development of Monolithic Motion-Detecting Components Made with MEMS Technology	Analog Devices, Inc.	3429
Development of the Submerged Electric Drive Cargo Pumping System	Westinghouse Electric Corporation	1735
Development/Application of Advanced Dual Use Microwave Technologies For Wireless Communications And Sensors For IVHS Vehicles	MA/COM, Inc.	1287
Diffractive Optics Technology for Battlefield Management Systems	Rochester Photonics Corporation	15002
Digital X-Ray System for Trauma and Battlefield Applications	General Electric Corporate Research & Development	1142
Diver Alert and Tracking System	Sonetech Corporation	14016
Dual Use Hydrostatic Bearing Program	United Technologies Corporation/Pratt & Whitney	2739
Dual Use Sensor Technology for Air Transportation System Capacity and Safety	Lockheed Martin - OR & SS	1309
E-Smart System for In-Situ Detection of Environmental Contaminants	General Atomics	5047
East/West Consortium: Next Generation Authoring Tools & Instructional Applications	Apple Computer, Inc.	2125
EcoScan - A Tunable IR Laser Remote Sensing System	Rockwell International Corporation	1162
Electric Variable Transmission	Allison Transmission Div. of General Motors Corporation	17013
Electron Bombarded CCD Camera	Intevac Advanced Technology Division	14018
Electronically Controlled Variable Displacement Vane Pump	Coltec Industries-Chandler Evans	1024
Experimental SONET OC-192 (10 Gb/s) and ATM Self-Healing Ring, An	Bellcore (Sonet Ring Team)	2595
Extrapolation of Adaptive Optics Technology to the Manufacture of Electronics and Next Generation Information Display Systems	AOI International	3149
Field-Deployable Continuous Monitoring Mass Spectrometer	Teledyne Electronic Technologies	5078
Fly-By-Light Advanced Systems Hardware (FLASH) Program	McDonnell Douglas Aerospace	3081
Gamma Ray Imaging System for Nuclear Environment Monitor	AIL Systems, Inc.	3079
Gas Generator Fire Suppression	Kidde Technologies, Inc.	17012
High Capacity Solid Polymer Battery Development	Lockheed Missiles & Space Co., Inc.	3249
High Power High Temperature Superconductor (HTS) Technology Development	COM DEV, Ltd.	1081

High Temperature Distributed Control Systems	United Technologies Research Ctr.	10015
Hybrid Propulsion Development Program (HDPD) [formerly Hybrid Technology Option Project (HyTOP)]**	Lockheed Martin Marietta	3612
HyperEducation Consortium	Enterprise Computing Institute	5026
IMAS: An Intelligent Modular-Array System for the Monitoring of VOCs in the Environment	Sawtek, Inc.	5055
In-situ Process Control for Growth of InP-Based Heterostructure Materials For Gigahertz Circuits	Hughes Research Laboratories	2126
Industry Common Building Block Electronic Modules	Lockheed Martin Control Systems	10014
Integrated Opto-Electronic Modules (IOEM)	Lucent Technology	2681
Integrated Small Precision Optics Manufacturing Technology	Rockwell International Corporation	15004
Interoperability Testbed For Diagnostic and Prognostic Maintenance of Equipment and Processes	Pennsylvania State Univ. Applied Research Lab	5035
ISMIS (Intelligent Shock Mitigation and Isolation System) Through Applied RSPM Technology	Enidine Incorporated	10005
Just-In-Time Maintenance	Northrup Grumman Corporation	2444
LEGOS: Object-based Software Components for Mission-Critical Systems	I-Kinetics, Inc.	5088
Lithium Ion Rechargeable Battery Development and Deployment	SAFT R&D Center	1380
Low Cost Electronic Packaging Through Systems Approach to Ball Grid Array Package Assembly	Ultra Clean International Corp.	5046
Low Cost Flip Chip	National Semiconductor	5163
Low Cost High Density Sequential Build PWB Manufacturing	Shipley Co.	5183
Low Cost High Performance Tooling By Three Dimensional Printing	United Technologies Corporation	3533
Low Cost Packaging Based on Area Bonding Adhesives with X Y and Z Axis-Conductivity	Merix Corporation	5069
Low Cost Packaging Technology for Automotive Electronics	Auburn University	5033
Low-Cost Plastic Packaging	National Semiconductor Corporation	5062
Low-Power High-Resolution Portable Ultrasound Imaging System	Teratech Corporation	12026
Manufacturing Process Development for Thin Multi-Layer (Flat Panel) Antennas	Raytheon Co.	17001
Microfabrication of Ophthalmic Surgical Knives Process Development and Mechanical Design	Johns Hopkins Hospital	2344
Miniature Filters For Wireless Networks	Northrop Grumman	13003
Miniaturized Environmental Monitoring Instrumentation Based Upon the Mass Spectrograph Chip	Westinghouse Electric Corporation	1648
Model Based Control and Diagnostics	GE Aircraft Engines	10018
National Academic Medical Center Information Collaborative	SAIC	2765
National Industrial Information Infrastructure Protocols (NIIIP)	NIIIP Consortium	2550
Next Generation High Resolution & Color TFEL Displays	Planar Systems, Inc.	5040
Object Technology for Rapid Software Development	Anderson Consulting	5165

and Delivery		
Pad Printer	MultiLythics	5011
Passive Millimeter Wave Camera	TRW Space and Electronics Group	1167
Portable 3D Imaging Ultrasound Systems Based on 1.5-D and 1-D Integrated Arrays	GTS/Albatross Technologies, Inc.	12013
Portable Shipbuilding Robotics	Cybo Robots, Inc.	3779
Portable Ultrasound Device for Battlefield Trauma	University of Washington	12014
Power Pak Mobile Electric Power System	Martin Marietta Armament Systems	2678
Precision Laser Machining	TRW	1493
Pyrotechnic Actuated Vehicle Rescue Equipment	Hi-Shear Technology Corporation	1197
Quick Reaction Spoken Language Translator (QRSLT)	Language Systems, Inc.	14030
Regional Technology Alliance for High Aspect Ratio MEMS Technology Development, A	Microelectronics Center of North Carolina	3798
Self Monitoring Advanced Remote Technology System	Auburn University	16002
Short Wavelength Optical Storage	Imation Corporation	5009
SiC Power Electronics for Affordable Next Generation Electric and Hybrid Vehicles	Northrup Grumman	17026
Solid State Oxygen Generator (SSOG)	CeramPhysics	1408
Spatial Division Multiple Access Wireless Communication Systems	ArrayComm, Inc.	2110
Surgical Simulation for Limb Trauma Management	MusculoGraphics, Inc.	1973
System for Noninvasive Arterial Blood Gas Measurement, A	Rio Grande Medical Technologies, Inc.	3184
Technology and Productization Acceleration of Low Cost Aluminum Nitride Electronic Packaging	The Carborundum Company	5095
Technology to Produce High Performance/Low Cost Interconnections for Flip Chip Attach	IBM Corporation	3327
Testbed for Digital Wireless Communications and Networking Systems	AT&T Corporation	13012
TI/Raytheon 'Leap-Ahead' Approach to U.S. Flat Panel Display Competitiveness - Field Emission Displays	Raytheon - Electronic Systems	5048
Turboalternator for Electric Hybrid Vehicles	CALSTART	2690
ULTRA	Inframetrics, Inc.	5135
Uncooled Infrared Sensors	Raytheon TI Systems (RTIS)	5093
Uncooled IR Microbolometer Sensor Cost Reduction Program	Lockheed Martin Infrared & Imaging Systems	5054
UV DIAL LIDAR	Litton / AMECOM	5043
Vehicle Management System Integration Technology for Affordable Life Cycle Cost (VITAL Program)	The Boeing Company	10022
Virtual Endoscopy	General Electric Company	12027
Volatile Organic Compound (VOC) Sensors Communications Processing and Display	Hughes Aircraft Company	5164
Wearable Computer Systems with Transparent Headmounted Displays For Manufacturing Maintenance and Training Applications	Boeing Computer Services	1033

$2000 Electric Powertrain 1616

Northrup Grumman

OBJECTIVE AND GENERAL STATUS: In this project, Northrop Grumman, which bought the original consortium leader, Westinghouse Electric Corporation, was to develop an electric

vehicle (EV) powertrain comparable in cost, power and smoothness to conventional internal combustion engines and powertrains. The goal of a $2000/unit cost was to be achieved with design for manufacturing methods that reduce Nothrup Grumman's break-even point for production. These methods also reduce the cost and boost the quality of electric motors while continuously embedding improvements in drivetrain technology and producibility.

MILITARY INTENT AND STATUS: With tactical ground vehicles moving toward stealthy multi-fuel operation and with tactical electrical power requirements increasing, the services must tap commercial markets to drive down unit costs and assure continuous technology improvements. High-efficiency electric motors, whether used for integrated wheel-motors or transaxles, offer improved power/mass efficiency over conventional all-mechanical drivetrains. Integral wheel-motors, for example, reduce weight and complexity over mechanical drivetrains by eliminating drive axles, differentials and transaxles, transmissions and power takeoff shafts.

Rugged high-power-density actuators also find a niche in Air Force programs for "more electric aircraft" flight controls that replace today's high-pressure hydraulic actuators, as well as in Navy shipboard electric drives that in the future could include main propulsion. Power electronics for these electromechanical systems represent another advance, with devices made from silicon carbide (SiC) now being used for high-temperature automotive applications.

The number of military "new starts" in general has dropped steadily since 1990. But, several programs, e.g., DARPA's Combined Hybrid Power Systems (CHPS) and Reconnaissance and Surveillance Tactical Vehicle (RSTV) programs, are using technologies from this TRP project, as well as from another TRP program in SiC power electronics building block (PEBB) electronics. According to the DARPA PM, the drivetrain will directly transition to the RSTV, now in development.

COMMERCIAL INTENT AND STATUS: The initial motivation for this project was the California Air Resources Board's (CARB) mandate for the 1998 introduction of zero-emission vehicles (ZEVs) and auto manufacturers' allocation of specified portions of their in-state new-car offerings to ZEVs and low-/ultra-low-emission vehicles (LEVs/ULEVs) by a specific date. California's actions are being copied by eight Northeastern states under the Northeastern States Council for Air Use Management (NESCAUM). Although California's 1998 ZEV deadline has been deferred in favor of a 10% fleet allocation for ZEVs by 2003, CARB and NESCAUM regulations continue to drive development of both pure EVs like the General Motors "Impact" and hybrid electric vehicles (HEVs).

Northrup Grumman's EV motors are being installed in school buses and Chrysler's pure-EV EPIC minivan. Northrup Grumman continues to reduce the breakeven point and is developing new technologies to drive down unit costs. They stress three markets: (1) EVs and HEVs; (2) industrial power generation; and (3) "more electric" defense projects like USAF's electric flight actuators. Northrup Grumman also has contracts in PEBB electronics that permit 100-kilowatt (kW) inverters to be built on a circuit board. They have exploited another TRP project, a turbine-driven alternator developed by Allied Signal, to expand its market. It has teamed with Allied-Signal to build a family of automotive and industrial turboalternators for distributed power generation and customer-site power generation: two markets whose trends promise to reshape the electric-utility industry.

Advanced Automatic Train Control (AATC) System 1126

BART

OBJECTIVE AND GENERAL STATUS: The purpose of this effort is to develop an Advanced Automated Train Control system. This system, based on defense communications technology the Enhanced Position Location Reporting System (EPLRS), is to provide the precise location of each train, even in tunnels. This will allow trains to operate with reduced separation distance, thereby doubling the passenger carrying capacity. At the same time, this system is expected to offer unprecedented safety, reliability and ease of retrofit to existing transit systems and to be applicable to rapid transit systems at half the cost of conventional technologies. In fact, the reliability demands are more stringent for this commercial application (due to safety considerations) than for the military system. This team originally consisted of the San Francisco Bay Area Rapid Transit (BART) District, Hughes Aircraft Company (HMK) & Morrison Knudsen Corporation (HMK). However, both HMK and Hughes (bought out by Raytheon) dropped out of the project. This problem was solved, however, when the consortium found and selected Harmon Industries, Inc. as their commercial arm. *Harmon, a U.S. based and owned rail signaling equipment supplier, has licensed the EPLRS technology from Raytheon for fixed guideway applications.*

MILITARY INTENT AND STATUS: The Army would like to reduce the cost of EPLRS by 40% (to 15K -$25K). If successful, the TRP effort would make this technology affordable to the military by cost reduction realized through commercial economies of scale, application of off-the-shelf commercial parts, and production efficiencies. The Army stated that it is relying on the EPLRS system for military command and control and position location at the unit level. No alternative systems perform all the functions expected of EPLRS, especially network management, and even the less capable systems will not be viable for years.

Differences between military and commercial systems are acceptable, if most parts are common. For example, the military radio operates at UHF band (450 MHz), while the commercial radio will function at 2.4GHz (better component availability) and anti-jamming and crypto-protection capabilities will not be included in the commercial hardware. Also, there are some operational differences. For instance, since the train is on a track, location can be determined by a single propagation time measurement, rather than having to triangulate, as in the military system. But no lessening of military reliability is contemplated. Other military systems that could profit from this project are the Navy/USMC PLRS, SADL EPLRS based system for the USAF, and an Italian EPLRS-based system, called CATRIN.

It is unclear how much savings was realized by the EPLRS system through this project. The lack of participation by the Army EPLRS Program Management Office was a major concern when we reviewed the project. Whether this was due to disappointment with the product, a change in the Army's acquisition plans, or some other factors, it reduced benefits the military might have received from the project.

COMMERCIAL INTENT AND STATUS: There is a good commercial market in train control systems. A study by Booz-Allen & Hamilton (that did not include all international markets) concluded that the current annual $400M global market in signaling and communications equipment for fixed guideway transit equipment could reach $2B within the next decade. Unfortunately, all but one of the dominant suppliers are foreign, so U.S. industry gets a small portion of the market. Sufficient reliability to meet mass transit safety standards is difficult for a radio-based system, but because of the Army's demands for reliability and anti-jam, EPLRS exceeds that of the system BART now uses. The principal benefit to BART is an increased system carrying capacity from 16 to 30 trains per hour in the trans-bay tunnel. This is equivalent to adding another tunnel. It also allows a 4% higher train speed.

The commercial system unit price goal was approximately $27K (for a lot of 400 units), from a current unit price of $53K. This represents cost savings of approximately 50% over existing track circuit-based control systems. Required commercial accuracy is 15 feet. for rail positioning, although improvements are being sought. Energy savings (via braking reductions) are expected to be approximately 11%.

Harmon Industries is currently redesigning the EPLRS-based AATC radio and will soon have a low cost commercial version of the original military radio. Their efforts to date have made it possible to market the AATC radio by the end of the second quarter of 1999. The cost reduction achieved is reported to be significant, but is not available at this time. Harmon will continue to fund efforts to reduce the cost even more. BART has executed a contract with Harmon to complete the development, with an option for the purchase of the system for installation of the at BART. It is fully expected that sales will occur in Asia, North and South America, and in Europe following successful installation at BART.

Advanced Communications Engine (ACE) 13016

Raytheon Systems Corporation

OBJECTIVE AND GENERAL STATUS: The objective of the Advanced Communications Engine project, led by Raytheon Systems Company, was to build a multi-band, multi-mode radio using a single path digital receiver that will let both commercial and military users "program" the radio's functionality. This can be thought of as allowing the radio's specific functions to be implemented through software instead of hardware (software can be altered or updated much easier than hardware). In addition, this approach may create cost reducing economies of scale in the hardware. The ACE will provide the capability to receive six simultaneous communications channels across five simultaneous bands. The project will also develop the software needed to implement various military communications waveforms and an encryption system.

Up to six channels of radio hardware using the ACE chipset was demonstrated in the laboratory on three 6U circuit cards. Original plans called for a build of a second ACE chipset, but it has been decided to build and demonstrate only one. Generic communication functions were programmed and tested for simultaneous operation, including: UHF and VHF frequency bands, AM and FM analog modulation, BPSK and FSK digital modulation, and the VOR navigation waveform. In addition, compatibility with the legacy military radio was demonstrated.

MILITARY INTENT AND STATUS: A software configurable multiband Multimode Radio will bring unprecedented communication flexibility to the warfighter. These capabilities will mesh well with the Army's initiative to "digitize the battlefield." The wide variety of potential commercial applications of this radio will help keep down the cost of the military radios. Dual Use is enhanced because software changes are all that is needed to convert from military to commercial roles. *The Advanced Secure Digital Radio (ASDR) is a technology development with 60 Unit Low Rate Initial Production (LRIP) to develop a small, multichannel intel receiver using ACE technology.*

COMMERCIAL INTENT AND STATUS: There are a wide variety of potential commercial applications of this radio, including marine, law enforcement, automobile, and cellular communications. *But, at this time there are no prospects for commercial sales of this product.*

Advanced Composites for Bridge Infrastructure Renewal 1230

University of California, San Diego

BACKGROUND: Polymer matrix composites, are fibers woven together and coated with a "plastic" resin. Durable, lightweight composites were originally developed for military aircraft and missile systems, but the technology can also be very profitably applied to the nations highway infrastructure. Over 30% of the bridges in the U.S. are structurally deficient or functionally obsolete, resulting in over 120 bridge collapses per year. While the U.S must retain polymer composite manufacturing capability, the Defense Department can no longer support the entire industry. Facilitating civilian use of composites in the nation's highway system, results in DoD gains by improving its ability to build and maintain mobile, lightweight bridges. However, even though composites for highway infrastructure and composites for Defense structures may not be exactly the same, the chemistries, processing technologies and manufacturing steps will be very similar, allowing improvements in one application through advances in another. Thus, the development of a robust commercial market for "high performance" polymer composites for highway infrastructure will lead to higher performance, lower costs and, most importantly, preserve that critical industrial base for DoD applications

OBJECTIVE AND GENERAL STATUS: The objective is to adapt polymer matrix composite materials for use in bridge construction and rehabilitation. Composite bridge structures will offer the advantages of rapid modular erection procedures, reduced construction time and cost; higher strength-to-weight ratios, permitting smaller and lighter foundations, abutments and piers; and superior corrosion resistance, reducing maintenance and extending service life. Bridge rehabilitation can use composite materials to replace cracked bridge decks, resurface roads with potholes, and replace crumbling bridge columns.

MILITARY INTENT AND STATUS: Polymer composites play a major role in military aircraft and missiles systems due to their superior structural and electromagnetic properties. The primary military effort on this project was to develop technology for a tank portable composite bridge. The bridge would be a replacement for the Vickers bridge that the Army presently buys. The cost and weight goals of the portable bridge were provided by the Army's Tank-Automotive Command (TACOM). *Phase I built and demonstrated one track of a portable bridge that met the cost, weight and performance goals of the Army.* The real significance of having achieved the TACOM devised weight requirement is that when the complete portable bridge is built one M-1 tank will be able to carry two bridges instead of the present one. The phase II program will build the complete bridge for the Army.

COMMERCIAL INTENT AND STATUS: The use of composites for the civilian highway infrastructure will greatly improve the structural integrity of bridges and other structures while simultaneously dramatically decreasing the cost of repair. A strategy for strengthening damaged bridge columns by retrofitting with carbon fiber jackets was adopted and tested on a large scale. *It was shown that such jackets are structurally as effective as steel, less costly, and can be applied 10-15 times faster. The carbon overlay system was demonstrated, via large-scale tests, to be effective for the repair/retrofit of concrete bridge decks. Also, a composite bridge deck system was developed to serve as a replacement deck or a new deck, weighing only 1/10th as much as a reinforced concrete deck, but having the same load carrying capacity. In addition, the consortium developed a radically new method to monitor damaged or weak structures, such as highway bridges. The developed system, called IntelliSense, uses a "smart" passive hoop sensor composed*

of a family of peak-strain-indicating metal alloys to measure strain. The technique has been successfully demonstrated for monitoring bridges, mines, and aircraft.

Advanced CTP800 Turboprop for Surveillance Aircraft 14026

Allied Signal Inc. – Engines

BACKGROUND: This project seeks to market a commercial variant of the AH-22 Comanche helicopter's T-800 turbine engine. The team seeks to recoup heavy corporate investment in T-800 development (total cost: $750 million) in anticipation of a DoD Comanche buy that has been cut more than 80% from initial forecasts. DoD likewise seeks to broaden the T-800 production base through variants like the CTP-800 for use in commercial and military fixed-wing aircraft. At project start, the team's planned CTP-800 military launch market was the re-engining of the Army's RC-7B "airborne reconnaissance - low" (ARL) aircraft. But when Army budget shortfalls led to its cancellation, the team shifted to the Ayres Corporation's short-haul Loadmaster aircraft, being built for FedEx and other customers. Loadmaster uses a "twin pack" of two CTP-800 engines driving two combiner gearboxes, which turn a nose-mounted propeller. Rated at 7500 pounds of cargo, it is ideal for military missions like short-haul tactical airlift, medical evacuation and airlift support for special operations forces (SOF) and also for commercial markets like regional short-haul passenger/cargo movement and amphibious operations.

OBJECTIVE: The project is intended to create a commercial home for the T-800, holding down its cost for Comanche. In developing and qualifying the Loadmaster's CTP-800 "twin pack," the team seeks to maintain maximum commonality (85%-90%) between the CTP-800 and its T-800 core engine. This reduces the production cost of the L-800 used on the Comanche and potentially on the re-engining of the UH-1 helicopter fleet.

MILITARY INTENT AND STATUS: The CTP-800 offers immediate performance gains for small fixed-wing turboprop aircraft now operated by the services. A re-engined RC-7B fleet would triple its productivity. The project reduces re-engining costs for hundreds of UH-1's and their derivatives now deployed with National Guard, Army Reserve and other units. Most UH-1's have the majority of their airframe life remaining. The Loadmaster can also replace the Air Force's C-23 Sherpa. The Loadmaster CTP-800 will acquire several hundred thousand operating hours before the first Comanche helicopter enters service with the T-800. Thus the CTP-800 can be a "fleet leader" for the T-800 in engine durability and quality control, with modifications fed back to T-800's in production for Comanche. *The project has met its technical goals but was delayed by the shift from the RC-7B to Loadmaster. The CTP-800 is in production. Loadmaster can be purchased as COTS by the services, assuring prompt military use of CTP-800.*

COMMERCIAL INTENT AND STATUS: The CTP-800 is ideal for new-build and re-engined short-haul cargo aircraft and regional passenger aircraft. *The CTP-800 is in production, with firm orders for 150 Loadmasters (300 engines, omitting spares), with options for 200 more aircraft (400 engines, omitting spares). The team is scouting other markets.*

Advanced Pictorial Archiving and Communication System (PACS) 2576

Lockheed Martin

OBJECTIVE AND GENERAL STATUS: The objective of this project is to develop an all digital radiology Picture Archiving and Communication System (PACS) for commercial and

defense hospitals. It will build on existing technology to extend it to a wide area system, add a mammography capability, and a voice channel. The result will be a storage and distribution system for imagery that will be interoperable (open architecture) with the medical community and serve the many digitization systems being developed for the medical field, such as computer radiology, digital x-ray, computer tomography, ultrasound, mammography, and so on.

This system has transferred to General Electric, who has sold a number of systems to military and civilian hospitals and clinics. This TRP product, developed and demonstrated by Lockheed Martin has now been handed off to a corporation that also produced a TRP digital medical system, the digital x-ray. It is obviously a good fit.[37]

MILITARY INTENT AND STATUS: This will enhance the DoD's Medical Diagnostic Imaging System. Loral, a defense contractor, is integrating with Georgetown Medical Center and UC Irvine to provide enhanced capability for the DoD's medical needs. *Thus far, the system has been installed and is being used in over 15 military hospitals and clinics, including Madigan Clinic in Lewis WA, Brooke Army Clinic in Texas, Walter Reed in Washington DC, and Ft. McPherson and Eisenhower in Georgia. It has improved the ability of these clinics and hospitals to perform and read medical imagery. For example, Ft. McPherson Clinic operates without a radiologist by transmitting the X-Ray images directly to the Eisenhower Clinic for diagnostics.*

COMMERCIAL INTENT AND STATUS: Sales of $500 million over the next five years are anticipated. *Thus far, PACS has been sold and is operating in 29 civilian hospitals around the world.*

Advanced Power Conversion Based on the Aerocapacitor 1229

Polystor

OBJECTIVE AND GENERAL STATUS: To develop an affordable manufacturing process for aerocapacitors, an inexpensive super capacitor which offers a five-fold increase in energy density over current capacitors (including packaging).

Higher energy density translates into more power stored in a smaller amount of space. Power-One, a commercial supplier of power supplies, has teamed with Lawrence Livermore National Laboratory, an originator of the aerocapacitor technology; Polystor Corporation, a capacitor manufacturer; Rockwell International, a consumer of capacitors and supplier of industrial automation, avionics, telecommunications, aerospace, graphics, and automation equipment; and Aerojet, a consumer of capacitors and supplier to defense, automotive, and polymer industries.

PolyStor has completed the development of the carbon aerogel capacitor. Charges are stored electrostatically in the electrochemical double-layer and can be released rapidly, providing specific power of up to 4,000 W/kg. Key developments have included a low-cost, simplified aerogel manufacturing process, lowering the resistance to one order of magnitude lower than other supercapacitors, and reducing the self-discharge rate. The aerogel capacitor operates at 2.5V per cell. Cells can be stacked in series for higher voltages and can cycle hundreds of thousands of times with minimal degradation. PolyStor has demonstrated the ability to produce 100,000 cells per month on a semi-production scale pilot line. Features of the aerogel capacitor include: extremely high power density, very long life-cycle, low resistance, low leakage currents,

[37] For more information, see the GE webpage: http://wwww.ge.com/medical/iis/index.htm.

wide temperature range, and low cost. The capacitor can be used for: hybrid power packs, digital (pulse) telecommunications, power conversion, power supplies, pulse power, actuators, air bag detonation, filtering, and audio and electronic applications. By leveraging their aerogel capacitor manufacturing technology, PolyStor has been able to enter the lithium ion battery market. This is a significant development as there are only few U.S. sources of lithium ion batteries, which are becoming more widely used in commercial and DoD applications. The major technical difficulty is leakage. The consortium is working on this.

MILITARY INTENT AND STATUS: Military applications in portable power include Global Positioning Systems, Laser Tag (for war games), Echoing Equipment, and a Hybrid Power Pack replacement for BB-590 for use with the SINCGARS radio.

PolyStor's Application group is currently working with the Army's Communication Electronics Command (CECOM) and a number of commercial customers including Motorola, Rockwell and Wireless Access to test current devices. The consortium has scaled-up production of the critical ultra-thin carbon electrodes, manufacturing more electrodes in one day than they had made in the previous two years. They are now implementing pilot production of a new cylindrical package design recently completed.

COMMERCIAL INTENT AND STATUS: Commercially, this prismatic cell will concentrate on very low resistance and new digital pulse telecommunications requiring high power requirements. If the potential anticipated for the energy density is realized in these capacitors, there should be substantial commercial potential for power supplies and other electronics applications. (e.g., hybrid power packs, digital (pulse) telecommunications, power conversion, power supplies, pulse power, actuators, air bag detonation, filtering, and audio and electronic applications). *Polystar is working with Rockwell to develop a commercial door lock application for pulse power capacitance.*

Advanced "Zero Emissions" Control Valve Development 3366

Target Rock Corporation

BACKGROUND: Because of their criticality and the fact that they handle highly radioactive, high-temperature liquids, the control valves of naval and utility nuclear reactors must not permit any leakage. This drove development of zero-emission valves (ZEVs) that do not penetrate the pressurized volume and directly contact the working fluid. By contrast, most control valves used in common industrial processes, from oil refining and chemicals to gas pipelines and pumping stations, use traditional stem valves whose moving stems penetrate the pressurized void. This requires stem packing and seals, creating inherent risks of leaks and emissions. With lower Navy shipbuilding budgets for nuclear carriers and submarines and with a static U.S. nuclear powerplant market, the nuclear market for ZEVs has nearly disappeared. Meanwhile, air pollution laws are driving industrial plant owners to replace millions of traditional valves. This convergence prompted Target Rock Corporation, the sole supplier of nuclear-reactor ZEVs, to commercialize its Navy valves in order to survive in a low-demand market for nuclear reactors.

OBJECTIVE: This project will transition solenoid-controlled ZEVs to industries (e.g., oil refineries, chemical plants, pulp processors) that must meet tough "fugitive emissions" limits for volatile organic compounds (VOCs). The valves' magnetically actuated, non-contact design allows rapid actuation, digital control and real-time network operation; the project will exploit such features. The team will first downsize and modularize the current solenoid valve and actuator to

meet a cross-section of commercial valve markets. It will also cut fabrication costs while retaining high reliability and quality. Other thrusts include dynamic (on/off) and modulated-control operation. The team will then modify the solenoid valve for full digital and "smart actuator" operations, while also qualifying valve designs for severe-environment operation: e.g., hot or corrosive fluids. The project will develop design methods that let the contractor rapidly customize valves for specific customers while building commonality into the valves to cut fabrication and design costs

MILITARY INTENT AND STATUS: The team targets the valve for the Navy's CVX next-generation carrier, the CVX and sees this project cutting the valve's costs by 40%. *The team is midway through the project and is beta-testing prototype valves at an Exxon refinery. It has briefed the Navy on the valve's design. The Navy is committed to evaluating the valve for use on the CVX.*

COMMERCIAL INTENT AND STATUS: The new valves' electronic controllability allows self-diagnosis and self-test, eliminating the costly inspection and replacement of stem valves. It lets them tie into digital control networks and use their embedded intelligence to host process sensors that otherwise require standalone mounting. It also allows on-line programming of the process streams to which they are attached. *The team is successfully beta-testing prototype valves at an Exxon refinery. It briefed the valve to the California Air Resources Board (the second most powerful U.S. regulator after EPA), which approved it for compliance purposes. Considerable work remains in moving it to market.*

Affordable Composites for Propulsion (ACP) 1428

Pratt & Whitney

BACKGROUND: Advanced engine designs now being considered for future production have the potential for increasing performance and fuel efficiency of both military and commercial aircraft. However, this potential can only be realized if much of the metal engine structure is replaced by polymer composites which can be affordably produced. This TRP project helps share the risk of demonstrating this technology while providing a unique mechanism for a partnership of polymer composite vendors, engine designers and airframe companies. If successful, this effort will enhance the U.S. competitiveness in aircraft production. as well as preserve a critical capability for DoD weapon systems.

OBJECTIVE AND GENERAL STATUS: This effort was designed to demonstrate low cost, reliable manufacturing approaches for composite structural components of propulsion systems to be employed in advanced aircraft. No new production processes were to be used. Specifically, this team of industries designed, fabricated and was to demonstrate engine outer and core cowls, fan blade containment, a fan exit case, and an engine pylon. An initial goal of a simultaneous 20 percent cost savings and 20 percent weight reduction for each of the selected components was envisioned. A specific Advanced Ducted Prop (ADP) engine, P&W's next major commercial engine product, was selected for hardware demonstration, the components of the ADP engine that are being addressed by the ACP Program represent a substantial portion of the engine and nacelle modules. *Numerous engine and nacelle parts have been fabricated by utilizing the two manufacturing approaches for composites manufacturing that are under investigation on this program: Resin Transfer Molding (RTM) and Automatic Tow Placement (ATP). On the average, the cost and weight reduction goals have been met, but in individual components there is a wide*

range of results. As examples, the military fan inlet case is 32% lower in cost and 43% lower in weight, while the fan cowl door is 29% lower in cost but weighs the same as the conventional composite honeycomb baseline and the fan containment case is 19% higher in cost but is 32% lower in weight than the aluminum isogrid baseline. A cost model developed under the ACP program is, for the first time, providing accurate cost estimates for composite parts so that companies are able to propose this technology in future engine programs. Since cost and weight can now be traded off against each other in these developments, the parts on the program were designed so as to make most sense in their application. A 10 fold increase in damage tolerance was also achieved on the program. This increase takes the composite material developed above all known threats to airplanes from natural environments.

MILITARY INTENT AND STATUS: Development of polymer composite parts for new high performance aircraft engines will result in lower weight and increased propulsion efficiency for DoD aircraft. *Military utilization of this work has already begun by supplying fan cowl doors to the C-17. The first military engine opportunity for implementing the fabrication techniques matured in this program will be for the Joint Strike Fighter (JSF)*.

COMMERCIAL INTENT AND STATUS: The commercial benefits are emphatically fuel and, therefore, cost savings. By using composites, an ADP engines will be weight competitive and will improve airline direct operating margins; a 12% improvement in thrust specific fuel consumption and up to 9000 lbs of weight savings per aircraft is expected. For every 1,000 lbs of weight savings $55,000 in additional revenue is obtained per aircraft per year. The P&W's PW8000 and GE's CF6 engines may incorporate composites. It is expected that ADP engines will replace over 300 large turbofans per year by the 21st century. The cumulative benefits of this product introduction is expected to exceed $500 million per year.

Air Quality Monitoring System Using a Neural Network Based FTIR Spectrometer 3275

AIL Systems Inc.

OBJECTIVE AND GENERAL STATUS: This project sought a rugged, portable passive electro-optical sensor whose size allows both fixed and mobile mounting (e.g., on a remotely piloted vehicle) for detecting and quantifying chemical warfare agents (CWAs). The device's dual use commercial roles included airborne pollution mapping, fence-line monitoring of landfills and hazardous waste sites, in-plant air quality control, detection of wastewater contaminants and in-situ inspection of automobile emissions.

The team focused on a family of "remote molecular monitors" (RMM): modular FTIR (Fourier Transform Infrared) spectrometers that combine improved signal processing, neural-net software and phenomenological understanding with the low per-unit costs allowed by production for large commercial markets. Spectrometers examine ambient or naturally emitted light arriving from a distance, detecting changes to the light's atmospheric path caused by contaminant molecules. This allows remote sensing (vs. short-range point sensing) of chemical warfare agents (CWAs) and also biological warfare agents (BWAs). In pre-TRP tests, an early version of the sensor achieved more than 50-fold sensitivity over current sensors. The sensor's neural-net algorithms, implemented in low-cost COTS hardware, allow RMM operation by nonspecialist operators.

MILITARY AND COMMERCIAL INTENT AND STATUS: In battlefield CWA sensing, the RMM would use background infrared sources of opportunity, while in commercial roles like fenceline monitoring it would use a retroreflector sited away from the sensor, giving it unequaled

sensitivity in volumetric scanning. Current Army FTIRs like the large tripod-mounted M21 use older signal processing methods that rely on background subtraction, ruling out deployment on mobile platforms like aircraft. By contrast, the RMM's high-speed processing detects CWA plumes against moving backgrounds, allowing RMM deployment on aircraft or moving ground vehicles. The RMM can detect CWAs masked by other emissions: e.g., terrorist CWA releases in transportation garages. The RMM works as a CWA alarm, with precise quantification of airborne agents being a secondary concern.

The project met its technical goals, detecting a CWA simulant at 18 km in Army testing. To qualify the sensor for commercial markets, AIL beta-tested the RMM prototype at two large New York and New Jersey landfills. It also sold two units for air-quality monitoring at two U.S. chemical plants and is pursuing Taiwanese and South Korean markets. The commercial RMM version, which played a major role in the development of its military counterpart, can detect 110 of the 189 CAAA-regulated hazardous air pollutants.

The military transition strategy calls for COTS buys of RMM to complement the M-21 FLIR. But defense sales are clouded by tight budgets. Proposed military uses include environmental monitoring, using a 100-lb, two-person RMM that AIL demonstrated at Tinker AFB, and a lightweight mobile battlefield CWA-detection alarm, which would use a different interferometry engine. The RMM's sensitivity and real-time CWA detection make it useful for a DoD standoff sensor like ChemSeek, a satellite-mounted chemical cloud-detection sensor whose focal plane array detector generates gigabit/second data rates; and a Lightweight Standoff Chemical Agent Detection (LSCAD) sensor for ground vehicles, UAVs and aircraft. LSCAD must detect CWAs at a 5-km range. AIL says its military version can be used by emergency medical service (EMS) crews and fire departments to respond to biological-agent incidents.

Aircraft Surface Contamination Detection Technology Advancement 3512

Rosemount Aerospace, Inc.

OBJECTIVE AND STATUS: The objective is to develop technology to accurately detect the presence of ice on aircraft surfaces, a capability that will increase the safety of flight in both the civilian and military sectors. This is accomplished by measuring the change in the structural response of aircraft surfaces resulting from the added weight and stiffness of ice. Initially, the project focused on ice detection prior to take-off. However, the FAA demands an essentially "clean-wing" (no ice) at take-off and the system could not detect ice at these small levels. The effort was redirected to focus on airborne measurement and glycol (deicing agent) effectiveness/degeneration. During flight, allowable ice build-up can be over one inch. Since measurements at this range of thickness is quite easy to attain with this technology, the firm continued to fund and market it and market the product.

MILITARY INTENT AND STATUS: The military value of this technology is essentially the same as that for the commercial sector. Prototype demonstrations and proof of final system designs have been successfully demonstrated on civilian aircraft (MD-80). Military transport aircraft have a special need for all-weather airlift mission capability, particularly when operating in fields lacking effective deicing equipment. In addition, a product capable of providing real time information alerting pilots to increasing/dangerous in-flight icing conditions will also be available to the military as a result of this product.

The military value of this technology is essentially the same as that for the commercial sector. Prototype demonstrations and proof of final system will be conducted on civilian aircraft first (an MD-80 is being used). But, at this time no military sales are anticipated.

COMMERCIAL INTENT AND STATUS: Even though the original product development was not capable of achieving FAA certification, the products produced from the refocused effort still have substantial commercial market potential. The products now available as a result of this effort include in-flight detection of ice formation down to .001 inch, measurement of glycol effectiveness prior to takeoff and a simple device that accurately measures available drinking water on commercial aircraft.

The commercial market is being addressed at this time. If successfully engaged, this market will provide a COTS product for the military. Rosemount is continuing to fund the development of the technology and is addressing the commercial marketplace with alternative products that resulted from this development effort. Sales are committed for 50 systems per year over ten years - 500 units total. Rosemount is also negotiating with Boeing Commercial Aircraft. The unit cost for a system that provides in flight ice detection and pre- flight glycol effectiveness is $50K.

Amorphous Silicon Medical Imager 2518

Ginzton Research Center (Varian Associates)

BACKGROUND: This is one of two competitive TRP projects to develop a digital (filmless) x-ray imaging system for mobile trauma care units in battlefield and civilian hospitals. The development of solid-state x-ray sensor will save lives on the battlefield by enabling rapid patient evaluation and accommodating consultation with physicians or medical personnel at a remote site (e.g., MEDFAST unit, forward of a MASH units).

OBJECTIVE AND GENERAL STATUS: The goal of this project was to demonstrate a 14 inch by 17 inch, full chest-size, x-ray imager system that could replaces the x-ray film cassette with a solid state imager. This imager will also have the capability to directly output the digital image so that it can be transmitted over the Internet; i.e. be teleradiology capable. A diode array built in amorphous silicon will act as the electronic sensor that will replace x-ray film at approximately one-eighth the cost of conventional x-ray processing and storage over the normally-required seven to ten year time period. *Shipment of imaging arrays and subsystems (array plus electronics) to x-ray equipment OEM's and to installed system retrofitters began in the fall of 1997. The sensor array performance is competitive with present day, x-ray diagnostic film (with 4 lp/mm spatial resolution, 8"x10" image areas, and low x-ray doses capable) or x-ray image intensifiers (with 2-30 frames per second data rates) and is superior to them in dynamic ranges (12 bit data), thus virtually eliminating the retake problem of film. The consortium has also demonstrated single tile sensors 12" by 16" in size (rather than the less cost effective 4 tile 14" by 17" version originally proposed) with 5 lp/mm resolution. The solid state, digital image recorders are made to exactly replace x-ray film holders in commercial x-ray units. The consortium has demonstrated its capability to remotely transmit x-ray images over the Internet.*

MILITARY INTENT AND STATUS: The ability to obtain digital x-ray images in combat zones and transmit them to the combat casualty evacuation location are critical to providing rapid medical care. The amorphous silicon sensor array will provide the last missing link for DoD's teleradiology systems already being installed. It will provide a truly one-step, diagnostic quality, instant x-ray image. It will speed up the administration of the appropriate treatment to injured

soldiers anywhere in the world during the first "golden hour" after injury when proper intervention can save the most lives and prevent the greatest disabilities. Digital satellite image communication permits real time viewing between any remote site and radiology experts situated anywhere else in the world. A particular benefit to the military comes from the ability of a limited number of expert radiologists being able to serve numerous medical clinics, where each clinic has a low individual radiology work load, throughout the world. In addition, this technology could play an important role in the military nondestructive evaluation (NDE) area. *Unfortunately, all efforts to interest the military medical facilities or the programs responsible for developing NDE technology have so far been unsuccessful because these facilities are apparently only interested in full systems and are not receptive to component manufacturers.*

COMMERCIAL INTENT AND STATUS: Replacement of x-ray film at one-eighth the processing and storage cost will provide mobile digital imaging systems that enable emergency shock and trauma units to diagnose patients at the scene of injury rather than much later after relocation to the hospital. Savings to national health is projected at $2 billion annually when this capability is fully implemented. The market for the medical imager itself is estimated at $500 million annually. The insertion strategy is to provide x-ray system OEMs with the solid state image sensor subsystem configured to directly replace their current film-based or image intensifier based (a vacuum tube) sensors. The end users will buy their x-ray systems from the same OEM vendors that they currently use. *Two separate business units have been formed to commercialize this product, Varian Imaging Products (VIP) at Varian and dpiX at Xerox, the other consortium member. Both sensors and sensor-plus-electronics subsystems have been sold to commercial x-ray systems OEMs such as Picker.*

Analog Optoelectronic Module Development 3541

Hughes Research Laboratories

BACKGROUND: Wideband analog transport of digital signals is far more cost-effective for a number of emerging opportunities such as interactive networks, wireless communications, cellular/mobile phone systems, electronic warfare, and advanced aircraft avionics. Despite the large market potential and recognized national defense payoffs, the pace of optoelectronics insertion into analog systems has been rather slow. No industrial base now exists to support this insertion.

OBJECTIVE AND GENERAL STATUS: The objective of this TRP activity is to develop a set of cost-effective, optoelectronic analog common modules which can transport analog (carrier-based) radio frequency (RF) signals over optical fiber. In addition to developing low cost modules, this program will execute several system demonstrations:

- Shipboard Electromagnetic Environment Monitoring: demonstration of remoting of a wideband (2-18 GHZ) Electromagnetic Field Probe for shipboard application,
- Auxiliary Antenna Array: will demonstrate antenna nulling using large baseline auxiliary antennas remoted by optical fiber,
- Demonstration of an RF Photonic Switch Network for next generation (Pave Pace) Air Force avionics,
- Very Small Aperture Terminal/Antenna Farm Fiber Remoting will demonstrate wideband antenna remoting for surveillance antenna systems by optical fiber,
- Cellular Radio will demonstrate remoting/interconnection of cellular radio antennas without the need for intermediate digitization/switching hardware, and;

- Smart Radio with programmable waveform.

Analog optoelectronic (OE) modules have been shown to provide capabilities that far exceed anything possible with presently used cables for RF, electromagnetic interference free, high bandwidth systems. Optoelectronic interconnect also provide large savings in weight and volume. However, the price reduction initially expected has not materialized since the commercial OE technology has concentrated on digital modules. Consequently, due to the lack of a commercial market for analog OE modules, the volume that is necessary to reduce cost has not been generated.

MILITARY INTENT AND STATUS: Virtually all military systems have a component which receives or transmits RF energy. Interconnections within these systems are made by special cables or waveguides, both of which are bulky, dispersive, and subject to losses. A highly effective alternative is make those interconnections with optical fibers. Carrying analog radio frequency signals over optical fiber is much more demanding than carrying digital signals (special low noise laser sources are required, as well as highly linear optoelectronic circuitry). But there are still persuasive reasons to do so. Optical connections are low-loss, small size, light weight, invulnerable to electromagnetic and RF interference, and are capable of handling very wide bandwidths. In these applications signal-to-noise ratio is very important, as is laser quality. Specific applications include antenna remoting, wide band phased array antennas with agile beam steering, electronic warfare, advance electronics for aircraft, missiles, and spaceborne platforms. This capability also has strong impact on the design of wideband/wide angular coverage phased array systems across a wide spectrum of applications in surveillance, communications and electronic warfare.

The OE modulator, one of the devices developed on this TRP program, has been inserted into a DoD "production" program by Uniphase Telecomm Products (UTP) for the fiber optic transmitter of the Lockheed-Sanders IDECM (Integrated Defensive Electronic Countermeasures) system. It is estimated that over one thousand aircraft will be equipped with this system. The modulator had also been selected by TRW Defense System for antenna remoting application. This latter program involved several hundred units. A number of other OE modules developed on the project had been successfully employed by NRaD/NCCOSC in a demonstration of ultra-wideband shipboard electromagnetic environment monitoring demonstration (on the USS Princeton).

COMMERCIAL INTENT AND STATUS: The global telecommunications infrastructure requires combined analog/digital signal transport. Analog fiber optic links offer efficient use of bandwidth and frequency. These links enable new wide band networks and systems that include broadband distribution networks, interactive video, voice and data services to residential and business customers; wireless communications; and commercial avionics providing information services to passengers, including multi-channel, high-quality video, games, telecommunications and personal computing. The estimated market size for analog optoelectronics modules is expected to grow to over 100,000 modules per year after the year 2000. *An initial sale of 1000 units at $1000 per unit of the optoelectronic modulator that enable wireless communications systems and antenna remoting for communication satellite ground stations has occurred.*

Asynchronous Transfer Mode (ATM) Interoperability Testbed 5111

Bellcore

OBJECTIVE AND STATUS: The objective of this project is to implement an Asynchronous Transfer Mode (ATM) interoperability testbed to develop tools, procedures and standards to promote interoperability among ATM products. Complementary to the efforts of the ATM Forum standards organization, the testbed will focus on the specific areas of signaling interoperability, traffic management and upper layer protocol interoperability over ATM.

MILITARY INTENT AND STATUS: The military must employ both military unique and commercial ATM products in the future. Involvement of the Joint Interoperability Test Center (JITC) will ensure this project will influence DOD network architectures. According to the government agent, "[m]ilitary requirements parallel commercial standards." MIL STD 188-176, Standardized Profile for Asynchronous Transfer Mode, governs the military use of this product. The JITC reviewed this standard with respect to DoD guidelines on testing (MIL Handbook 1350-1/," validation of Data Communications Protocols for Military Applications" and concluded that the consortium-developed test tool was adequate with respect to the desired military functionality."

Both software and hardware were tested in the Interoperability Testbed during the project. NSA links were used, so all testing pertained to both the military and commercial sectors. The government agent indicated, "the JITC evaluated the product in a military network to ensure its performance in an NSA-approved encrypted environment. The product performed its essential network test functions without degrading either the commercial or military application.....The JITC, as the certification authority for the DoD, has approved this product for Joint Service use."

DoD will purchase this equipment through COTS sources, as required by the current DoD acquisition guidelines. Near term potential uses for the product will be found in the DISN and other large scale networking programs. The Military Service development laboratories, the Defense Information Systems Agency, and the National Security Agency were solicited to sponsor further development of this product under the Dual Use Applications Program, but none had the discretionary funds at the time.

COMMERCIAL INTENT AND STATUS: *The software from this project was licensed to two companies making test equipment: ADTECH and GN Nettest. Customers for their products can also buy this software.*

Automotive Collision Avoidance System (ACAS) 2430

Delco Electronics

OBJECTIVE AND GENERAL STATUS: Automotive engineers, federal safety regulators, insurance companies and auto-safety activists have long sought technologies to reduce highway fatalities, injuries and property damage. One promising technology is a collision warning system (CWS) that merges data from front-, rear- and side-viewing sensors and alerts the driver of pending rear-end collisions by sound cues, a head-up display (HUD) or by a vibrating steering wheel or foot pedal. The automotive market is inherently attractive to DoD as an innovative, cost-disciplined production base for dual use radar and electro-optical (EO) components, particularly low-cost millimeter-wave radar (MMW), currently used in terminal-guidance radars on air-launched weapons, and monolithic microwave integrated circuit (MMIC) devices for night vision systems and HUDs. For as automotive sensor markets grew in sophistication and size, market forces will drive down the cost of CWS sensors while promoting better performance and durability. Particularly attractive to DoD were mass-producible EO CWS sensors and mass-

producible CWS radars, the latter using MMIC and gallium-arsenide devices that historically had been restricted to costly military systems.

This project focused on long-range EO and radio frequency (RF: "radar") CWS sensors to detect hazards ahead of the vehicle, short-range sensors to detect hazards behind or to the vehicle's side, and a lane-detection system to alert the driver to vehicle deviations from the intended traffic lane. To cut costs, the team opted to refine existing or immature technologies and drive down their manufacturing costs while accelerating development of CWS sensors. It planned a design-for-manufacturing strategy to drive down the cost of MMIC-RF devices used in CWS radars. A strong "dual use" focus seemed assured by the team's inclusion of the largest of the U.S.'s "Big Three" automakers (General Motors) and two GM subsidiaries experienced in mass-producible automotive electronics (Delco) and high-performance MMW/MMIC technologies (Hughes Research Laboratories).

MILITARY AND COMMERCIAL INTENT AND STATUS: *The project had limited success. It demonstrated advances in EO, vision and radar sensors, including a simple forward-looking CWS radar, a lane-detection system, a rear-looking and backup CWS, a side-looking near-object detection sensor, a wide-field-of-view HUD, a laser-based cruise control sensor, a set of reliable and producible MMIC radar transceivers, a planar forward-looking 76-GHz MMIC radar, major cuts in missed-detection and false-alarm rates, and high-performance scene-tracking algorithms for complex high-clutter settings (e.g., forward-looking CWS on curving multi-lane roads or sharp corners).*

But from DoD's viewpoint, the project was a failure and yielded no militarily useful or market-ready commercial hardware. Achieving a mass-producible CWS radar proved more difficult than expected. The team's planar forward-looking 76-GHz MMIC radar, for example, was too costly for automotive use although it was five times cheaper than current units. To meet its CWS-radar performance and cost goals, the team dropped its planned all-MMIC, all-planar forward-looking CWS radar in favor of a conventional mechanically scanned radar with traditional discrete components. This removed DoD's central motive for participation: encouraging commercial mass production of MMIC radars. Even with this switch, the team's major hardware success (a reduced-cost radar transceiver) was not commercially affordable although its size was reduced to ~100 cubic inches. The prototype sensor cost $200,000 – when the market required a $500 dealer's cost for the radar and its display. However, Hughes formed a Microwave spin-off to make commercial radar modules, which may allow low-cost generic MMIC radars.

Automotive Micromachined Gyro and Derivative Applications (also called MAGIC: "MEMS Applied to Guidance, Instrumentation and Control") 16005

Boeing North American (formerly, Rockwell International Corp.)

BACKGROUND: MAGIC draws on the first MEMS (microelectromechanical systems) market: automotive airbag sensors, antilock braking systems/traction control (ABS/TC), and anti-yaw and roll-control sensors. These markets require low-cost, extremely reliable, high-performance micro-accelerometers, single- and multiple-degree-of-freedom (DOF) gyros, and integrated packages that are stable in performance over wide ranges of shock and temperature, yet mass-producible in silicon for inertial measurement units or sensing assemblies (IMU, ISA) used in guidance, navigation and control (GN&C). Reaching the navigation-grade IMU accuracy needed in guided weapons and car navigation (MAGIC's focus) demands less temperature susceptibility (a problem for silicon) and low drift rates.

OBJECTIVE: The team's goals cover high-volume producibility (10 million units/year) of a 1x1x1 millimeter silicon MEMS gyro as a building block for 2-DOF ISAs for ABS and ISA insertion in commercial and defense products (e.g., the Marines' Predator missile). The team also seeks gains in batch yield, throughput and cost. Planned derivatives cover dead-reckoning car and heavy-truck gyros, specialty test instruments and a 6-DOF ISA for Predator-type weapons. For MAGIC, DARPA sought a first-axis cost below $500 per ISA. Typically, 2nd-axis costs are 30%-100% of 1st-axis costs.

MILITARY INTENT AND STATUS: The automotive gyros, IMUs and multi-DOF ISA's based on the team's core product (a 2-DOF ISA) need drift rates of 0.1-1 degree/second for their planned "entry-level" use in seeker stabilization and GN&C for short-flight-time missiles. Drift-rate improvement to 0.1 degree/second will let the team's ISAs go into standoff air-to-ground missiles (Maverick), smart gun shells, air-to-air missiles (AIM-9X), autopilots, and stabilizers for antennas and FLIR (forward-looking infrared) sensors. For MAGIC, the Predator program planned a hardware-in-the-loop simulation of a 6-DOF ISA; the Army stressed artillery and mortar shell GN&C. *The project has gone well, with multiple transitions. MIT's Draper Lab built a core rate sensor that exceeded predictions in indices like drift rate, as well as application-specific integrated circuits (ASIs) for cheap shock-tolerant, low-power, low-drift-rate IMUs. Draper greatly reduced MAGIC drift rates, with a 6-DOF IMU as a goal. The Marines bench-tested MAGIC for Predator. MAGIC flew successfully as an alternate ISA on the new Navy EX-171 5-inch smart shell, whose initial production run totals 2,500 rounds, with total production of 40,000-60,000 rounds. MAGIC can also be fitted to an Army 155-mm gun shell and a mortar round and the Air Force's Wind Corrected Munition Dispenser (WCMD). In a dual-use space role, Boeing will use MAGIC devices in a small shuttle experiment locker.*

COMMERCIAL INTENT AND STATUS:. MAGIC is targeting mass-producible ABS priced for both low- and high-end cars (vs. current ABS orientation to the latter). *Endevco and WABCO successfully tested MAGIC in test instruments and heavy-truck ABS, respectively. Endevco reports good results in sampling MAGIC-upgraded instruments and expects to produce 5,000 units per year. WABCO envisions initial production requirements of 25,000 units.*

Autonomous Landing Guidance (ALG) 3462

Lear Astronics

BACKGROUND: The ALG project is led by Lear Astronics, with United Airlines as the commercial user for operational requirements, and the 412th Air Force Flight Test Squadron, which provided a Speckled Trout, a 707 aircraft used by the Chief of Staff of the Air Force. The ALG was integrated on this aircraft and a commercial 727.

OBJECTIVE: The objective of the ALG project was to demonstrate through the combination of display and sensor technology that pilots could conduct hand flown flight operations in low visibility conditions without the use of ground aids. The system uses information either from millimeter derived radar data or from a Forward Looking InfraRed (FLIR) to project a real-world image of the runway and airport onto a HUD.

MILITARY INTENT AND STATUS: The benefits of an ALG system to DoD are highlighted by the many military operations in which weather has severely limited flight operations. Besides the costs of aircraft not being able to complete their mission and having to abort back to their alternate bases, the ability to project power, deploy forces, re-supply and to complete humanitarian

operations regardless of the weather is an operational necessity. Additionally, a visual image of the runway in poor weather, increases safety since runway obstacles and damage to the runway surface would be seen. There is also considerable military advantage in operating when others cannot, thus achieving the tactical advantage of surprise when combat operations necessitate operations in low visibility conditions. Pilots will be able to land in CAT IIIA low vision CAT I equipped runways. Important benefits will result in support operations for conflicts such as Desert Storm.

The ALG Program is currently being evaluated by the USAF for application to the C17 and C130. The intent is to develop a "First In" capability in which aircraft would be able to conduct autonomous flight operations in low visibility conditions anyplace in the world. The military, following the deficiencies highlighted by Bosnia, are now accelerating the requirement for a "First In" capability to achieve a 50 foot capability with the goal of zero ceiling/zero visibility operations.

COMMERCIAL INTENT AND STATUS: The commercial interest in ALG is driven by the airlines' losses due to weather, most runways are not equipped for lower visibility operations and, according to United Airlines, they are losing approximately $150M a year on weather related delays. Commercial market opportunities will depend on timely FAA certification. Anticipated revenues are of the order of $70M by the year 2000. Substantial impact on the U.S. economy may be gained through indirect job creation. The commercial requirement drove the initial testing with the intent of demonstrating the ability to conduct Category III (50 feet, 700 feet required visual range) operations on Category I facilities (200 feet, 2400 required visual range). The ALG essentially would provide the added integrity and replacement for runway lighting and markers in gaining credit for lower minimums. This would open up more than 1,200 Category I runways in the United States that are now not available, even if the aircraft is Category III equipped.

Airlines are not yet signed up to this. The FAA testing is not completed. Certification is still required. Until the product is certified the airlines will not book a sale.

Beam-Agile Active Transmit Phased Array System 3655

SS/L (Space Systems/Loral)

OBJECTIVE AND GENERAL STATUS: This project meets demands for new high-performance mass-producible communication satellites whose electronically controlled direct-feed transmit arrays can control beam characteristics and ground spots more precisely than current arrays. This boosts satellites' radiated power five-fold in communicating with satellite phones and small (<1 meter) USAT (Ultra Small Aperture Terminal) ground dishes, correcting their signals for weather and other effects, and precisely shaping the ground contours of their spot beams. Such contouring allows new satellite communication markets like high-bandwidth computer-to-computer and Internet links, imagery distribution, and PCS satellite and cellular telephones. These require satellites that can precisely target ground zones and shift coverage as needed. Satellites with "active transmit phased arrays" (ATPA) can track national coastlines and boundaries without wasting capacity and power on unpopulated ocean zones, unlike older satellites with less precise beam shaping. Conventional transmit arrays use a precisely machined indirect-feed reflector dish custom-shaped to the contours of the ground area being served and its required services. This customization complicates repositioning the satellite's spot beams or modifying its coverage to serve new markets or to replace a failed satellite. It rules out mass production, with each satellite's critical features essentially fixed for the lifetime of the satellite (10 years or more).

Competing ATPA-based satellites are mass-producible, have longer lifetimes and can be flexibly assigned to military or commercial service as needed. Such dual use flexibility is important, as frequent U.S. military deployments increasingly demand high-bandwidth, quickly positioned satellites that can relay imagery to and from small ground dishes. With DoD's bandwidth needs growing despite reduced defense budgets and fixed frequency allocations, military satellites must be reconfigurable to adapt to changing needs. The overlap between commercial and military downlink frequencies allows military planners to exploit the mass-producibility of ATPA satellites and use commercial providers for military satellite communication needs.

ATPA permits a "distributed array" design offering more redundancy than do current transmit arrays, allowing loss of up 10% of arrays without compromising the satellite's performance. ATPA satellites can incorporate new non-TRP-funded receiver arrays in a multi-beam array (MBA) for excellent anti-jam nulling of intentional and unintentional interference. ATPA arrays can be extended to EHF (extremely high frequency). More significantly, combining a single MBA and a single ATPA reduces spacecraft weight by 1,000 pounds in comparison to Milstar. This reduction allows a multi-band payload to be launched by a medium launch vehicle like the Atlas II or IIA, rather than requiring a far more expensive heavy-lift launch vehicle like Titan 4 or shuttle.

MILITARY AND COMMERCIAL INTENT AND STATUS: *This project, which experts call very demanding and risky technology, was a partial success. SS/L underestimated ATPA's technical problems and overestimated its near-term commercial attractiveness. SS/L focused on a 37-element, 2-4 beam array covering military spread-spectrum downlinks (Milstar) and commercial fixed and mobile satellite downlinks. The team's work covered K-band MMIC (monolithic microwave integrated circuit) devices, advanced power amplifiers and controller chips for closed-loop control of multi-beam arrays. Despite a major change and numerous setbacks in control-subsystem design and development, the team met its Phase 1 goal of defining a flight-qualified electronically steerable phased array and exceeded its performance goals for MMIC devices. SS/L ended the project before building and testing an integrated ATPA array (Phase 2,) but is continuing work on ATPA electronics. But ATPA's military-transition prospects are unclear. SS/L has transferred ATPA advances to its Globalstar satellite network. The technology divergence between ATPA and Globalstar downlink frequencies makes dual use benefits unclear. Similar arrays are being developed for DoD use by Hughes (a 64-element, 2-simultaneous-beam array), Lockheed-Martin and TRW. Future transition of SS/L's ATPA to DoD use will probably come through SS/L subcontracting.*

Combat Surgical Ultrasound System & Probes with Multi-Modality Image Fusion, for Front Line Surgical Guidance & Telesurgery 12005

Tetrad Corporation

BACKGROUND: The Army seeks to improve front-line combat care through minimally invasive surgery (MIS) with laparoscopic probes, gripper/manipulators, video cameras, "surgical navigation" and image-guided surgery. While most casualties transported to field hospitals survive, a large percentage of wounded die from severe bleeding before they can be transported. This toll can be cut by front-line surgery based on a quickly erectable "fast tent" surgery unit or on remote (tele-) surgery, which in the near term could use "augmented reality." MIS probes can be quickly inserted into the wounds themselves or into small incisions. This makes forward surgery much faster, simpler and less logistically demanding in setup time and equipment than conventional open surgery. But whereas in the latter the surgeon's hands and eyes can directly palpate and assess tissue and organs, MIS relies on intra-operative imagery from probe-mounted ultrasound imagers or from external imagers using ultrasound, magnetic resonance imaging (MRI) and computerized tomography (CT). Ultrasound imaging presents organs and tissues in thin "slices" at 10 times MRI and CT resolution. It also can image pooled and circulating blood, data critical to assessing combat wounds. To be interpreted, ultrasound images must be properly placed in the surgeon's field of view, with appropriate visual cues. The images must be merged into an easily interpreted display and, if needed, merged with pre-operative MRI and CT images or intraoperative images from laparascopic video cameras.

OBJECTIVE: This project targets "fast tent" in the near term while creating building blocks for augmented-reality remote surgery. It focuses on image fusion, an MIS guidance system and imaging probes whose piezoelectric materials allow steam sterilization by front-line autoclaves.

MILITARY INTENT AND STATUS: The project is on schedule and meeting its goals, but is in a hiatus at present. *Tetrad expects a $10,000-$20,000 briefcase-size system weighing less than 20 pounds. Army clinical trials in 1998 saw enthusiastic endorsements from Army surgeons. The project's future service transition will be decided at a February, 1999 DARPA meeting on combat medicine, leading to further trials or a follow-on system. The team also is marketing its transducers for diver-held sonars for mine countermeasures, object identification and characterization, and underwater navigation.*

COMMERCIAL INTENT AND STATUS: Civilian uses cover trauma care and outpatient care in which MIS replaces far costlier traditional open surgery. MIS is used in only 4% of 22 million surgeries annually in the U.S., but is growing rapidly. The team expects to sell at least several thousand ultrasound-guided MIS systems. It sees a large commercial market providing continuous technical and procedural refinements that can be fed back into military casualty care. To target this high-growth market, *the team has added a vendor in surgical-tool position, location and navigation and another that plans a low-cost system to succeed Tetrad's costlier system.*

Commercial Shipbuilding Focused Development Project 2140

Bath Iron Works

BACKGROUND: Navy shipbuilding in the U.S. is diminishing and the shipyard industrial base will suffer unless it can become commercially competitive in the world market. Bath Iron Works (BIW) has designed and constructed over 400 Naval surface combatants and commercial vessels since its birth in 1884. During the early 1990's, BIW had decided to pursue the international market for high technology commercial vessels.

OBJECTIVE AND GENERAL STATUS: The stated objective of this activity was to:
i) Lead the U.S. Shipbuilding industry's reentry into the global commercial shipbuilding market.
ii) Reduce the cost of Navy ships [through economies of scale, efficiencies, and technologies].
iii) Preserve the shipbuilding industrial base through success in the commercial market.
iv) Provide dual use merchant marine vessels through innovative ship designs.
v) Provide a number of benefits to the U.S. economy, yielded by the expansion of this industry.

A hard look at the overall strategy revealed that the surveys of market and competition yielded bad news -- the Return On Investment (ROI) was insufficient to compensate the extensive amount of effort required to compete in the commercial market (most particularly in the low technology ship market). The company concluded that, while there is an increased demand for commercial ships, the purchase price was decreasing. Additionally, the company asserts that dominance of low technology ships in the market, plus continuing foreign subsidies of their shipbuilding industries, and a 40% worldwide production over capacity make the present market difficult, even for established foreign commercial shipbuilders. So, the decision was made to concentrate on the naval ship market until market conditions improved and/or commercial viability was proven (e.g., the market could shift toward higher complexity, which would favor entry by BIW). This decision recognized that continuing downsizing of the shipyard may result. In the late 1990's BIW was bought by General Dynamics, which is a large Navy shipbuilder.

However, there was some very good news. Relationships, which remain intact, were created with Kværner Masa-Yards and Mitsui Engineering and Shipbuilding. Further, technologies and processes were imported through these relationships that were successfully applied to Navy shipbuilding, more than compensating the government for its TRP investment. The second benefit of the project was the analysis of modernization of BIW's facilities needed to compete with world class commercial shipbuilding facilities visited during the survey. A comprehensive blueprint of a state-of-the-art dual use facility was generated and is being implemented as time and finances allow. Later, the DARPA PM used this project as a model for the MARITECH Program, a cost shared, five year effort to encourage commercial ship building in the U.S. From the time of its initiation, MARITECH supplanted TRP as the source of funds for dual use shipbuilding projects in DARPA.

MILITARY INTENT AND STATUS: Defense would benefit from lower cost, better availability of on-shore sources of Naval ships through a more economically stable U.S. shipbuilding industry, and a larger industrial base to serve national defense. Some of the merchant ships designed under the TRP were to be adaptable for roll-on/roll-off. Adoption of commercial standards by the Navy would help to reduce their costs and to improve chances of BIW's entry into the commercial market.

Projects initiated as a result of the technology transfer have produced annual savings of $11 - $13M in material handling and management and production labor on current Navy contracts. These changes are reducing the cost of construction for the Aegis destroyers currently being built at Bath and will also save the navy money on the construction costs of the LPD 17. Further, it was reported that the DD-21 Hull design was an off-shoot of this project.

COMMERCIAL INTENT AND STATUS: The commercial benefit was to be the U.S. Shipbuilding industry's reentry into the global commercial shipbuilding market, with benefits to the industrial base, dual use merchant marine vessel, and U.S. economy, discussed earlier. *But, there are no plans to address the commercial marketplace at this time.*

Commercialization Demonstration of Mid-Sized Superconducting Magnetic Energy Storage Technology for Electric Utility Applications (SMES) 2224

Babcock & Wilcox (BWX)

BACKGROUND: Large amounts of electrical power can be stored in "superconducting magnetic energy storage" (SMES) coils at cryogenic (e.g., liquid nitrogen) temperatures, then discharged into high-power devices like EM catapults or self-defense lasers on aircraft carriers or into commercial electric power networks. Early electric-utility interest in SMES stressed diurnal storage: charging SMES with cheap power at night for daytime peak periods. Deregulation, competition in power quality and declining generating margins now drive interest in using SMES to offset the dips and surges in network power that can damage computers, industrial process controls and consumer electronics.

OBJECTIVE: This project is developing a mid-size SMES energy storage unit whose performance (30 megawatts (MW) of power, 1800 megajoules (MJ) of energy) and affordability make it attractive to the Navy for aircraft catapults and to electric utilities. The participating utility (Anchorage Municipal Power and Light: AMPL) sought SMES for "spinning reserve" backup power to prevent brownouts in a system geographically isolated from other large power networks. The SMES unit would also provide operational data for SMES-driven electric aircraft catapults (EMALS) for the Navy's next-generation carrier (CVX) and for energy storage on all-electric ships that use electric propulsion.

MILITARY INTENT AND STATUS: SMES gives ships an "integrated power system" (IPS) for propulsion, auxiliary power, actuators and self-defense weapons, eliminating the separate hydraulic, mechanical, electrical or chemical power technologies needed for such systems. Navy studies of shared SMES applications across Navy, non-Navy military and industrial uses of SMES found two Navy uses with strong commercial benefits: an EM aircraft launcher system (EMALS) and IPS. The Navy has explored both for its next-generation "CVX" carrier, with EMALS also a retrofit candidate for Nimitz-class carriers. EMALS reduces Nimitz's costly, manpower-intensive steam catapults and cuts catapult mass, volume and manning. A SMES-IPS allows stealthy propulsion and one-engine cruising and can replace emergency power generators. *The project, largely industry-funded, is a partial success. While Navy CVX plans remain fluid, the technical risks posed by EMALS require early utility deployment of a SMES unit in the EMALS performance range. This is not occurring, although the project has changed its utility participant and the utility role proposed for SMES (power quality -- vs. an earlier emphasis on storage). The new design is a better fit with EMALS. The team awaits federal approval of the new utility participant and is continuing work on its own.*

COMMERCIAL INTENT AND STATUS: Utility deregulation quickly changed the project focus. When AMPL opted against storage at the end of Phase 1, the team replaced it with AEP (American Electric Power). *AEP plans to co-fund and test a midpower SMES for power quality and transmission stability on its large networks in the South. This unit is a better fit with EMALS. BWX is continuing work on the AEP design while awaiting Department of Energy approval of the change in utility participants in the project.*

Commercialization of DOD IUA Vision Computer: An Enabling Technology for CAD-Directed, Vision-Guided Robotics for Flexible Manufacturing (2114)

Amerinex Artificial Intelligence, Inc.

BACKGROUND: Defense R&D in image understanding (IU) has progressed to the point where it is ready for use in a variety of DoD applications. The main drawback for use in DoD systems has been the prohibitive cost. Recent trends in COTS hardware developments are beginning to overcome past limitations of high performance hardware that have impeded development of practical IU applications. These developments include achievement of lower costs, decreased size, standardization, and new processing techniques that facilitate IU-type computations. Effective integration of state-of-the-art IU software technologies with such COTS hardware can now provide IU application solutions previously not possible.

OBJECTIVE AND GENERAL STATUS: The objective of this effort is to develop IU products by using and enhancing existing IU software technology that can utilize COTS hardware. The Consortium will also analyze image understanding (IU) applications in terms of market and computational requirements. They will then select and develop the most promising defense and commercial applications(s) for delivery on COTS hardware. These products will demonstrate the feasibility and methodology for the practical use of IU software technology for both military and commercial applications. This program is designed to reduce the cost of implementing such IU architectures, making them competitive in the near term market. *Via three revisions of the statement of work (SOW) the consortium has arrived at a three tiered approach to IU products: Low Stress products that can run on standard personal computers (PCs); High Performance products that require a workstation type computer to execute; and Bridge Products that will enable users of existing IU tools/systems such as the Aphelion, Khoros and the IUE to utilize the strength of each system and to share developments and results.*

MILITARY INTENT AND STATUS: Defense will benefit directly from the emerging "dual use" markets such as medical imagery, security and surveillance, intelligent character recognition and robotics for all applications. In addition, a strong commercial market will drive down the cost and improve the capabilities of this technology to the point that it can be effectively incorporated in a multitude of DoD systems. Specific IU applications with significant relevance to DoD missions include: target acquisition, reconnaissance, unmanned aircraft/ground vehicles, detection of concealed weapons, through-the-wall imaging and general surveillance. *The High Performance products are all millimeter-wave imaging product, mostly designed for security, operations other than war (OOW), and other clandestine observation markets. Products developed in this category are the Gateway Scanner, the Hand-Held Scanner and the Through-the-wall Imaging System (TWIS).*

COMMERCIAL INTENT AND STATUS: By expanding IU software support for the new generations of COTS hardware, growth of computer vision markets, both military and commercial, will be substantially stimulated. *Low Stress products developed are the Graphics Region Analysis, Raster-to-Vector converter, Microscopy Fiber Analysis and, as a byproduct, the Aphelion IU tools. 63 Aphelion Tools, 15 Vision Tutors and 23 Khoros Compatibility software has been sold. Sales projections are for 3,600 Aphelion tools in the next 5 years; 40 Microscopy Fiber Analysis tools next year, 100 per year for the next five years thereafter; 112 3D Microscopy tools in the next 5 years; 15,000 Graphics Masking tools in the next 3 years; 13,000 Raster to Vector converters in the next 3 years; 80 Gateway Scanners in the 1st year and 200 in the 2nd year; 10*

Hand-Held Scanners in the first year and 175 in the 2nd year; 500 Vision Tutors in the next 5 years; and 800 Khoros Compatibility tools in the next 5 years.

Competitive Low-Cost Packaging for Wireless Communications in a Global Market 5114

National Semiconductor Corporation

BACKGROUND: This project provides a foundation for improvements in wireless communications for both military and commercial programs and has a strong product driver to maintain and enhance the technology being developed. In an effort to reduce the cost of wireless communications, the consortium was formed to develop a low-cost, fully integrated digital transceiver for wireless telephone applications. This new technology will accelerate the development and deployment of Low Temperature Co-Fired Ceramic (LTCC) products in the wireless communications marketplace worldwide. The original program lead company was Hughes Aircraft, however, National purchased the LTCC manufacturing facility and technology from Hughes and assumed leadership.

OBJECTIVE AND GENERAL STATUS: The team was to develop a LTCC substrate technology which incorporates both wiring and passive components, low-cost encapsulation for sensitive devices, high-volume assembly and test techniques, active RF components, and design tools. To demonstrate the technology, a fully integrated wide-band advanced digital transceiver, that integrates advanced mixed signal semiconductors with passive inductors, capacitors and filter elements within a common substrate, was to be fabricated. Specific goals included the reduction in passive components by 65% and 4X reduction in module size. This will reduce costs for many RF electronics applications by reducing component count and assembly costs. *The program goals were met. National demonstrated a Voltage Controlled Oscillator plus phase-locked-loop, needed in both military and commercial wireless communications, with embedded inductors and capacitors. The product is close to production and a version intended for military systems, is currently under evaluation by Lockheed-Martin and Northrup-Grumman. By introducing commercial products into the LTCC line, National has increased line utilization from <10% to >80%, resulting in significant cost reductions for all products manufactured on that line.*

MILITARY INTENT AND STATUS: Military applications include transceivers and receivers for airborne communications and guided weapon systems, data and voice communications via satellite links, higher quality surveillance systems for intelligence gathering in the presence of increasing numbers of potential threats, and infantry support on the battlefield. For military applications, the consortium members have designed, built and tested an IF receiver for a wireless data link for missile telemetry and real time updates of missile guidance to enhance target acquisition. *The redesigned modules integrated most of the passive components producing an RF module that was over 4 times smaller than the current printed circuit (PC) board version and had eliminated solder connections for enhanced reliability. 300 prototype units of a LTCC based digital signal processor (DSP) package have been provided for use on the F-22 program. There is ongoing interest for other insertions of this technology in military systems, both for RF and digital applications.*

COMMERCIAL INTENT AND STATUS: Commercial applications were targeted at cellular phone base-stations and handsets. *The program successfully designed, built and tested a module that integrated over 50% of passive elements in a Voltage Controlled Oscillator and Frequency Synthesizer thus reducing the cost of the assembly by 2x over printed circuit (PC) versions, while*

reducing size by greater than 4x. 250,000 LTCC preamplifier substrates and 4,000 38GHz Point-to-Point Data Links have been sold. High volume use is expected in next generation digital phones such as the U.S. personal communications system (PCS) and the digital European cordless telephone (DECT). National has received seed money from several telecommunications companies in the U.S., Europe and Asia to develop components for cellular phones, pagers, and other infrastructure products. The world-wide market potential is forecast to be anywhere between $50B and $120B annually by the year 2005.

Computer-Aided Earth Moving (CAEM) With DP-GPS 3353

Leica (formerly Magnavox)

OBJECTIVE AND GENERAL STATUS: In order to boost productivity and shorten construction times, military and civil earthmoving operations must minimize or eliminate time-consuming, labor-intensive precursor surveying and topographic analysis, and must reduce their dependence on operator skills for precise grading.

MILITARY AND COMMERCIAL INTENT AND STATUS: This need is particularly urgent for manpower-limited U.S. military construction forces called upon to rapidly build airfields, port facilities and other forward facilities for rapid-projection forces. Yet the soldier-drivers deployed with these construction units may lack the years of experience to rapidly translate lines of pre-surveyed flagged stakes into precise blade elevations and angles. Army force-planning studies like Force 21, Army After Next, and Engineer 21 see a need for rapid precision construction that can be achieved with average soldiers. Accurate vehicle self-location is also needed to help trucks cross partially cleared minefields and for other applications.

Although differential-positioning GPS (DP-GPS) satellite-navigation signals and "laser plane" guidance are available for precise horizontal and vertical positioning, respectively, such reference data traditionally has been displayed separately to the driver, whose skill levels in combining it and translating it to blade and vehicle positions now become the main determinant of precision. Prior to this project, combining both data streams in real time for direct blade control required processing power that was considered too costly for routine use by construction crews.

The team (Magnavox/Leica, Caterpillar, Spectra-Physics and Army Corps of Engineers (CoE)) decided to directly control the earthmoving blade by combining high-speed processing of satellite navigation signals, acquired by GPS receivers attached to each end of the blade, with military laser guidance developed for air-delivered munitions. Direct blade control eliminates precursor surveying and stake lines and lets lower-skill drivers achieve high grading accuracies. Complex surfaces (e.g., vertical, horizontal or super-elevated curves) could be achieved on demand, much as a numerically controlled milling machines precisely machines metal parts out of raw stock. To use CAEM, CoE site engineers would first drive a CAEM/GPS-equipped survey vehicle over the site to map its natural elevation. They would then superimpose the desired 3D model on this site reference map and use the difference to drive the earthmover's blade.

The project finished on time with excellent demonstration results. All three corporate partners are marketing complete or partial CAEM systems for new earthmovers or as retrofits. Although budget problems ruled out CoE tests, the Army can buy CAEM-equipped earthmovers off commercial lines. A Caterpillar study for CoE found that CAEM offered major productivity gains over non-CAEM earthmovers. CAEM also permits construction at night or in low visibility conditions and can guide vehicles on cleared corridors through minefields. Commercially, the

team sees CAEM as a U.S. marketing edge in a highly competitive global market. CAEM can also be used for other precision operations like precise blasthole drilling in open-pit mines or precise planting of crops.

Consortium - The Path to a Globally Competitive MCM Industry in the U.S. 3087

MCM-D Consortium

BACKGROUND: Multiple Chip Module (MCM) technology, a new method of interconnecting integrated circuits on a common substrate, recently has become the key to increasing performance and reducing size and cost in the microelectronics industry. A consortium under the umbrella of the Electronic Industry Foundation brought together the emerging participants in this new industry.

OBJECTIVE AND GENERAL STATUS: The MCM-D consortium was set up to forge relationships among the industrial partners, assess emerging technologies, and plan programs for joint and individual execution. Two goals were to drive the development of advanced manufacturing equipment specific to Thin Film MCM (MCM-D) packaging and to large area assembly associated with MCM-D modules. The end objective was to significantly reduce the cost to manufacturing MCM-D electronic modules. Specific goals were to lower module cost to <$10/sq. in., a 10X improvement, lowering assembly/test costs to $3-10 per chip, a 3X improvement, and achieving a total manufacturing cycle time that is just 2 times the actual processing time, a 5X improvement. At the conclusion of the program it is expected that the program will have laid the foundation for a robust and self supporting infrastructure of domestic suppliers for MCM production equipment and materials, providing the foundries with a capability for rapidly (3 to 4 weeks) prototyping and cost effective manufacturing of both high and low volume MCM modules, and having reduced the investment cost of establishing a basic MCM facility by 3X. *The consortium is well on its way to achieving a production capability for 600 mm by 600 mm (large format) manufacture of MCM-Ds. The necessary equipment is in various stages of commercial viability. A large area sputtering system funded by the Consortium is already a commercial product, other funded equipment that are about to become commercial products are a high speed wire bonder and an automatic inspection tool.*

MILITARY INTENT AND STATUS: Bringing the cost of MCM devices down to the point where the U.S. has market dominance is critical to assuring that DoD systems are built with the state-of-the-art technologies that will reduce size and weight of electronic systems. The program will also assure DoD access to the MCM-D technology. The military will derive a major benefit from this TRP by being able to obtain better performing and cheaper MCMs in the future.

COMMERCIAL INTENT AND STATUS: If MCM costs were to come down - the goal of this program - the U.S. market for these devices is projected to be in the $30-$40 billion dollar range by the year 2000. The U.S. MCM industry was in an embryonic state and its supplier industry was highly fragmented, thus lacking direction and the resources to invest in an orderly program to gain world leadership in this critical electronics technology. *Under the direction of the MCM-D consortium the industry has brought about the realization of a number of critical tools necessary in the manufacture of MCM-Ds. Intervac is selling a large format MCM systems capable of uniform sputtering over 1 m by 1.3 m and Palomar has produced a pre-production high-speed, large-area gold wire bonder capable of 6 to 8 wires/sec. Other developments that will become commercial products include: a laser ablation system built by Anvik, capable of both metal patterning and via hole drilling through a low-cost aluminum mask; on IBM built/ Integrated*

Solutions marketed flying probe tester to detect shorts and opens; Beltronics is in the process of developing two commercial inspection systems; Tamarack Lithography built a 600 mm by 600 mm scan system that will be further developed into a step and scan system with 10 micron resolution; Allied Signal produced a large format electron beam curing system to achieve low temperature dielectric curing with reduced stress and increased throughput; Research Devices supplied large area flip chip bonders; and Intarcia and Georgia Tech developed a large area panel materials for substrates.

Cryo-Electronics for Microwave Systems 17004

Superconductor Technologies, Inc. (STI)

BACKGROUND: Operating conventional microelectronics at cryogenic temperatures (below -50C) boosts their performance in such metrics as noise level, component degradation and circuit cycle time (i.e., electron transit time). These payoffs are especially useful in complex integrated circuits (ICs). By integrating high-temperature superconducting (HTS) filters, delay lines and resonators with suitable semiconductor components and operating these assemblies at cryogenic temperatures, engineers can build high-performance radio frequency (RF) and microwave systems. Military systems benefiting from HTS insertion include radars, electronic warfare and radio frequency (RF) signals and communications intelligence (SIGINT, COMINT). Used commercially, HTS boosts the detection sensitivity, selectivity and signal-to-noise performance of filters, protection circuits and low-noise amplifier combinations in cellular-telephone base stations.

OBJECTIVE: This project sought to fabricate and demonstrate three kinds of dual-use HTS microwave devices: circuitry for radar receiver protection and clutter automatic gain control (AGC); series-connected switched-band reject filters for radar warning receivers; and a high-selectivity, low-noise receiver front-end filter/amplifier for personal communication systems (PCS). These devices also would demonstrate common manufacturing processes for reliable, cost-effective HTS microwave circuits, as well as microwave packaging and cryogenic packaging of systems, including cryogenic cooling of conventional semiconductor components.

MILITARY INTENT AND STATUS: Military benefits extend to radars (better detection and tracking); electronic warfare (better interference control for detecting weak signals in electronically dense environments); and greater signal-to-noise discrimination and range for RF signals and communications intelligence (SIGINT, COMINT). *The team met all technical goals for the three dual-use device types. STI is transferring the technology to Northrop Grumman for military products. Military variants of the PCS filter, which triples detection range for weak signals, are being field-tested by an intelligence agency and by Air Force SIGINT/COMINT aircraft. Both users strongly endorse them. The radar circuitry will be tested in a Navy-run Advanced Concept Technology Demonstration (ACTD) featuring a Lockheed Sanders surface-wave radar for surface ships that can detect low-flying cruise missiles at twice today's over-the-horizon detection ranges. STI is funded to match the team's devices and processing methods with the highest-leverage defense applications. It finds strongest military interest in COMINT and SIGINT.*

COMMERCIAL INTENT AND STATUS: The targeted HTS-insertion market is in protection circuits, filters and low-noise amplifier combinations for cellular-telephone base stations. HTS thin-film filters can replace large commercial resonance-cavity filters in such cellular components, dramatically reducing their size and boosting their sensitivity and selectivity, allowing wider geographical cellular coverage and better discrimination against interfering signals. *The team was*

successful with all three dual-use devices and has commercialized the front-end PCS filter, in production for one year. The team's cryocooling methods also boosts performance of non-HTS conventional circuitry. In recent tests, a SPARC 20 workstation's CPU (central processing unit) chip. improved its clock speed by 50% (from 125 MHz to 185 MHz) when cooled to -50C from the chip's current ambient operating temperature of 80C..

Customer Driven FED Manufacturing Partnership 5051

Candescent Technologies Corporation

BACKGROUND: Assuring the commercial availability of affordable, high-performance flat-panel displays (FPDs) has worried DoD for over a decade. The growing information intensity of combat makes the display a major factor in warfigthers' combat performance, yet current cathode-ray tube (CRT) displays (basically small TVs) are fragile and unreliable. Such FPDs face unique requirements for broad temperature range, sunlight readability, shock resistance, maintainability in harsh environments and power draw. DARPA's High Definition Systems (HDS) program funds leading-edge R&D in helmet-mounted displays (HMDs) and larger displays, from desktop/laptop size to command-post size (e.g., 120-inch diagonal) FPDs. HDS seeks improvements in life-cycle cost (LCC), mean time between failure (MTBF), weight, ruggedness and power efficiency. Yet DoD cannot afford the high unit prices of small production runs of military-unique FPDs. Meanwhile, most major U.S. computer integrators buy their FPDs, especially the benchmark AMLCD (active-matrix liquid crystal display) FPDs, from Asian vendors. This dependency has led DoD toward dual use FPD options and next-generation FPDs that match or outperform AMLCDs but are domestically producible.

OBJECTIVE AND GENERAL STATUS: This project pursued an attractive non-AMLCD option, the field-emission display (FED), which uses millions of tiny cathodes rather than the CRT's one large cathode. FEDs are considered brighter, more power-efficient and more producible than AMLCDs, which basically are giant (e.g., one foot diameter) integrated circuits whose manufacturing steps are very demanding and costly. Using technology from Silicon Video Corporation (now Candescent), the project emphasized low-cost manufacturing technology for medium-size FEDs. Candescent focused first on high-volume commercial markets, which it believes will cause FED production costs to decline as maturity and experience increase over time. Low-volume military FED production would be realized at this point. By contrast, the strategy pursued by Raytheon in a separate TRP project in FEDs calls for low-volume initial production for military uses, then a transition into high-rate commercial production.

MILITARY AND COMMERCIAL INTENT AND STATUS: *The project has met all milestones but one (a pilot line making 40-50 FEDs/week) and is continuing under a no-cost extension. Candescent has raised over 10 times as much private capital ($365 million, with another $100 million planned) as its TRP funding, all aimed at a $500-$600 million FED production rated at 500,000 FEDs/year. It believes that only sustained throughput at this production volume can drive unit prices down to mass-market levels. It underestimated the cost and time needed to qualify all FED mass-production technologies, but is using commercial money to solve its problems. It is allied with Hewlett-Packard to integrate its FEDs into HP products and also with over 10 vendors, many investing on their own, to build an FED manufacturing infrastructure. It is tackling the PDA (personal digital assistant) market, the riskiest and most demanding cost market, and plans early-1999 pilot production of 5.3-inch high-resolution FEDs for sampling to integrators, users and a military service. This line is also developing a 14.1-inch FED for laptops. Candescent plans to market to DoD in 1999.*

Demonstration of Universal Electric Transportation Subsystems (DUETS) 2390

NovaBus (formerly Transportation Manufacturing Corporation)

BACKGROUND: This project addresses an important convergence between military and commercial hybrid-electric vehicles (HEVs) in propulsion, vehicle management systems (VMS) and active suspension. Military HEVs like the Marines' stealthy "reconnaissance, surveillance and targeting vehicle" (RSTV), trucks and light armor need compact, rugged wheel motors, efficient motor/generators and energy-storage systems charged by constant-speed diesels or turbines. Meanwhile, many cities have imposed air-pollution laws that are driving operators of diesel-powered stop-and-go vehicles (especially buses) to HEVs. This raises operators' entry risks, for stop-and-go bus duty is the toughest, most technically challenging duty cycle in the automotive industry. Modern buses and tanks both host complex VMS networks of sensors, actuators, communications and displays. Active suspension, used in high-performance cars, is also attractive for military vehicles' cross-country performance. The anticipated size of domestic and foreign markets for low-emission buses, whose features and needs overlap with heavy military HEVs, promises economies of scale and product improvements for the latter.

OBJECTIVE: This project targeted a high-efficiency, lightweight integrated electric wheel-drive drivetrain, a semi-active suspension system and a VMS for HEV buses and wheeled military HEVs up to 40,000 lbs. Both HEVs will combine low-emission diesels with battery packs for rapid acceleration and short-duration power for hill climbing or passing.

MILITARY INTENT AND STATUS: The DUETS drivetrain enables medium-weight military HEVs. Its high power density in a small package reduces wheel and suspension weight and overall vehicle weight. Its dual-use design allows military variants to be optimized for high power density, with civilian versions derated to lower power density for longer life, lower maintenance, etc. Depending on their onboard storage (high-performance batteries, flywheels), DUETS vehicles also can divert electrical energy to onboard and offboard payloads: e.g., radars, communications posts, electronic jammers and other payloads needing electric power normally provided by a mobile generating set. By contrast, conventional vehicles use APUs (auxiliary power units) for auxiliary power. Overall, DUETS creates an HEV production and product-improvement base on a scale that no military program could achieve alone. The services' large truck fleet also creates potential replacement markets for DUETS. DUETS' industrial base in the long term will reduce DARPA's HEV development costs, improve drive components programs through a growing sampling population and generally reduce risk for DoD's HEV programs.

The project has produced few military benefits and its has no firm transition prospects. Its wheel motor is an outstanding success, achieving the highest power density for such motors (135 horsepower (hp) continuous, 258 hp peak). Although the team emphasized propulsion power, it explored methods to increase output power several-fold for auxiliary payloads. DUETS-driven HEV components also feed into the Army's future battle tank, now planned as an HEV. DARPA sees DUETS battery packs and motors as useful for Hummer-based HEVs and other vehicles employing transaxles. But there are no firm near-term developmental vehicles that could use DUETS drive components. DARPA sees DUETS wheel motors lagging in performance behind induction motors for DoD use and therefore will not baseline DUETS for use in its programs. It also sees no military use of the VMS or semi-active suspension, which is tailored to unique transit-bus problems

COMMERCIAL INTENT AND STATUS: According to the DUETS consortium, they offer an alternative to "alternative-fuel vehicle" (AFV) and "flexible-fuel vehicle" (FV) engines that reduce pollution through new fuels (methanol, compressed natural gas (CNG), biodiesel) and costly engine modifications. NovaBus sees DUETS outperforming CNG diesel buses in emissions and life-cycle costs. With DUETS, transit operators can avoid building costly new fueling and maintenance infrastructure while reaching the emission reductions that originally drove the development of AFVs and FFVs. DUETS allows current diesels to run at constant speed, their lowest polluting mode. Other payoffs include excellent traction control, improved fuel economy, reduced noise and heat, and electrically (vs. mechanically) driven auxiliary systems (air conditioning, etc.). A DUETS bus can use its onboard electrical power for auxiliary lighting, signals, external displays or other electronics. The fault-tolerant VMS network (used on Boeing's 777 transport) has never failed and can add "hooks" for smart-highway communications, vehicle tracking and fleet management.

NovaBus expects to sell a fleet of demonstration buses in 1998-1999. It seeks 3-5 test sites with 5-10 buses per site as a DUETS demonstration fleet, including five-bus fleet for New York City. Indicating its confidence in DUETS, it will offer the bus as its preferred product for transit-system bids written for AFV and FV buses. But providing adequate production quantities of DUETS drivetrains (from Kaman Electromagnetics) is a challenge. NovaBus Kaman are studying ways to boost production to commercial scale.

Demonstration & Spin-Off of the Integral Motor/Propeller Propulsion System 2319

Westinghouse Electric Corporation

BACKGROUND: The reduction of Navy ship procurements has had major impacts on many defense industries. Westinghouse, Electro-Mechanical Division (WEMD) is an interesting example of such an industry. Until 1970, about 70% of WEMD's sales were commercial, but during the 1980's and 1990's defense became their primary market (65 to 70% of sales). Although there was a slight increase during the Reagan years, declining shipbuilding budgets resulted in business reductions at WEMD that reduced personnel from 1,348 in 1992 down to 580 in 1995. This project was conceived as a way to address the commercial market -- to use WEMD's skills to compensate for the drop in DoD funds and to produce savings through the commercial marketplace that would be passed on to the Navy.

OBJECTIVE AND GENERAL STATUS: The Integral/Motor Propeller emerged from the "canned motor" concepts that WEMD used in designing the Integral Motor/Propulsion (IMP) System for Navy submarines (e.g., the Seawolf). As yet it is only used on submarines, but is being considered for other Navy applications (the Navy tried the IMP for Seal-delivery boats). The basic idea was to apply this motor concept to the commercial market -- to furnish electric propulsion system for boats and ships. After a market study (which included an independent survey), it was decided to propose the motor for either a primary propulsion system or as a "positioner " (an ancillary system) for commercial ships and boats. The motor would replace conventional equipment like "z-" and "L-Drives." Since it was recognized that military sales would be quite low, the proposed commercialization of the IMP would reduce unit costs through commercial economies of scale, which could be passed along to the Navy.

Unfortunately, despite optimistic findings from the initial market survey, it was decided later that the commercial market was smaller than WEMD had anticipated and the company terminated the project.

MILITARY INTENT AND STATUS: The IMP was designed to serve as the Secondary Propulsion Unit (SPU) for the Seawolf submarine. Although there are distinct advantages to the IMP (e.g., reduces cavitation, improved stealth, reduced weight), military sales are projected to be extremely low. The establishment of a commercial market was to enhance availability and affordability.

COMMERCIAL INTENT AND STATUS: Market analyses originally indicated a potential to generate $50M of sales per year within the first 5 years of commercialization. This would have resulted in the capture of a larger share of the international maritime industry market, displacing foreign firm sales in the U.S. and positioning a U.S. manufacturer in the worldwide ship propulsion market. Commercial applications were to include tug boats, ferries, yachts, service vessels, coastal tankers, cargo ships, and other vessels.

Deterministic Design, Manufacture and Assembly of Aspheric Optics 15003

University of Rochester, Center for Optics Manufacturing (COM)

BACKGROUND: This project is led by COM established by the Army at the University of Rochester. Affordable optical systems in use today consist solely of spherical and plano components which are easily fabricated. However single spherical elements introduce optical aberrations that must be corrected by adding more spherical elements. Properly designed aspheric elements will correct aberrations and can be used to replace two or three spherical components. Optical systems using aspheres will provide better optical performance than the best all-spherical (near) equivalent. Less optics also improve transmission.

OBJECTIVE AND GENERAL STATUS: This TRP partnership was to develop and demonstrate new fabrication and assembly processes and technologies that, for the first time, will give optics designers and manufacturers the ability to lower fabrication cost by 10X and consistently use aspheric elements in optical systems. Reduction in size and weight, and improved performance of advanced optical systems was to be demonstrated on both military and commercial systems. The systems selected were the Target Acquisition and Designation System & Pilot Night Vision Sensor of the Apache Helicopter, the Digital Micromirror Device, and the Advanced Digital Camera. *A first prototype of deterministic Asphere Grinding machine, built by Nanotechnology, has been delivered to COM. The consortium defined the machine specifications and is providing hands-on applications engineering and constructive feedback for the production of the commercial machine. This equipment, operating under flexible computerized numerical control (CNC), has demonstrated 10X cost reduction over diamond-turned aspheric optics. It is capable of machining aspheres in brittle materials such as glass and silicon, materials that are far cheaper than the materials practical for diamond turned optics. The computer-controlled microgrinder produces precision ground (<0.5 l) lens surfaces with low subsurface (< 2.0 micron) damage in minutes. This grinder substantially reduced the follow-on polishing required. Of particular significance was further polishing by magnetorheological finishing, which is a computer controlled deterministic polishing technology. Another manufacturing tool, Optipro's CF100 Cementing Fixture, was provided for rapid, precision assembly of optical doublets, lens cells and aspheric subassemblies. The assembly system has been demonstrated to achieve assembly tolerances of < 0.005 mm, cycle times of less than 1 minute and set up times under an hour, and has the unique capability that it does not require the assembled lenses to have the same diameter.*

MILITARY INTENT AND STATUS: Military markets that can benefit from this program include laser range finders, night vision systems, missile seekers and precision guided munitions. Optics manufactured using conventional grinding processes can necessitate non-recurring costs of $10,000 to $50,000 per design and recurring cost of $100-$800 per part. The estimate for manufacturing aspheric optics using the technologies developed by this program are a non-recurring cost of $1000-$5000 per design and a recurring cost of less than $10-$80 per part. Systems needing such optics include Javelin, UAVs, M1A2 tank and the U.S. Army's advanced laser eye protection binocular objectives. *Raytheon and Lockheed Martin have provided applications analysis for future systems and Raytheon is incorporating aspheres into its High Resolution Ruggedized Display development.*

COMMERCIAL INTENT AND STATUS: Optics and electro-optics will be key component technologies in the 21st century. The market is forecast to be greater than $100 billion by 2001. *The consortium members are actively pursuing this market. Nanotechnology Systems is expecting sales of 30 to 50 machines per year of their 150AG Deterministic Asphere Grinder. Optipro has developed the CF 100 Cementing Fixture that is a precision assembly system for optical doublets, lens cells and aspheric subassemblies with diameters ranging from 10 mm to 100 mm. 2 to 3 machines will be sold to Kodak and there are presently prospects for 6 to 8 more machine sales. Opkor is sees business opportunities with volumes as high as 2000 lens assemblies per week. Both Raytheon and Kodak are using aspheres in their optical systems; the processes and machinery developed in this TRP will lower the cost of such assemblies and thus increase sales.*

Development of Application Software Hierarchy for Reuse (DASHR) 5154

Template Software

BACKGROUND: Modern software systems are among the most complex human-made structures ever built. The high software dependence of defense functions like battlefield communications, electronic warfare, data fusion and real-time situation assessment, as well as the services' need for robust, distributed software networks for chaotic environments and mobile users, requires advances in software generation and reusability to cut development cost and time and improve software evolvablity. Similar problems bedevil non-defense software users. An August, 1998 Presidential Information Technology Advisory Committee report noted that both sectors depend on fragile, unreliable software whose development, testing and evolution are labor-intensive and difficult. Escalating software demand, led by growth in computer performance, Internet connectivity and software-intensive communications, sensing and control networks, far exceeds U.S. software production. Tools for constructing and analyzing software are inadequate. The growing complexity of systems, growing shortages of software programmers, nonstandardization, and poor upgradability create a "software crisis." DoD also tends to buy software not as components (modules) but as all-new custom software.

OBJECTIVE AND GENERAL STATUS: One solution pursued by this DASHR (Development of Application Software Hierarchy for Reuse) project is building libraries of certifiably robust, reusable software building-block modules (objects). Software developers today must manually integrate tools and applications, which cannot be reused on other projects because of lack of standards. Often they must recode functional prototypes written in older languages into newer portable languages like C++. Current CASE (computer-aided software engineering) tools allow only limited prototyping, do not support system evolution and do not allow user perspectives on

evolving systems. DASHR thus focused on objects and software-engineering aids that embody emerging object-management standards. It targeted two applications: a Preventive Medicine Planning Tool (PMPT) for guiding military planners in preventive medical treatment of soldiers going overseas, with a second spin-off (an Air Campaign Planning (ACP) tool), and a commercial in-line Batch Manufacturing Scheduling (BMS) tool for flexible manufacturing.

MILITARY AND COMMERCIAL INTENT AND STATUS: *The DASHR TRP project achieved ~70% of its objectives. The original focus, a real-time ACP tool, was dropped in favor of a generic non-real-time Strategic Planning Toolkit (SPT) that led to two products for the Navy: PMPT and a medical waiver advisory tool, developed with residual project funds, to help the Navy find positions for personnel who do not meet full physical-health requirements. DASHR software can also be used in battle management tools like ACP. Template and its team members are also selling DASHR tools commercially. IBM is a major presence in turnkey and custom software packages and business software for enterprise integration and electronic commerce, while Honeywell sells software for flexible manufacturing. Several project tools are now available free from the Internet.*

Development of Monolithic Motion-Detecting Components Made with MEMS Technology 3429

Analog Devices, Inc.

BACKGROUND: DoD's first priority for early insertion of MEMS (microelectromechanical systems) lies in small, accurate, reliable and cheap MEMS motion sensors: high- and low-acceleration ("G") accelerometers, inertial measurement units (IMUs) and other GN&C (guidance. navigation and control) devices. Such units replace today's larger, costlier, less reliable and lower-performance "macro" devices that integrate precision-machined metal parts with "pick-off" electronics. Being micromachined with CMOS-compatible processes from materials now used in integrated-circuit (IC) semiconductors, precision MEMS sensors can be mass-produced cheaply on modified IC production lines. But in order for the services to fully exploit such motion sensors, developers must choose robust baseline designs optimized for one or more of three military sensing parameters: high-G and low-G acceleration and gyroscopic angular-rate sensing. In pre-TRP work, the team pursued all three types and also an "iMEMS" design and fabrication process for 2nd-generation motion sensors with better feature density, more performance and lower production costs. The team sees production costs of $5-$10/unit for its dual-use sensors.

OBJECTIVE: The team addressed low-G accelerometers for GN&C; high-G accelerometers for fuzing, safing, and arming (F/S&A) of missile and artillery warheads, drawing first on ADI's airbag sensor, then using "iMEMS" for multi-component MEMS chips (vs. today's single-accelerometer chips); and angular-rate gyroscopes as adjuncts to conventional sensors. Other thrusts covered manufacturing processes and development of shared design and production standards and mask libraries with MCNC (Microelectronics Center of North Carolina) a DARPA-funded consortium specializing in high-aspect-ratio MEMS.

MILITARY INTENT AND STATUS: The team targeted smart F/S&A devices for artillery shells, micro-micromachined gyros and IMU chips for tactical-weapon GN&C, vehicle GN&C, personal navigation devices for soldiers, low-cost two-gyro units for aiming stabilization of rifles and for aircraft yaw control, and production methods for MEMS magnetometers. *The team met all its goals, developing a 3-axis high-G sensor (now in service sampling); one- and two-axis low-G sensors; and angular-rate sensors, including gyros of near-navigation-grade accuracy, surface-micromachined gyros and gyro/accelerometer chips for multi-axis IMU chips. An unmodified*

commercial device gun-launched at 30,000 G's performed perfectly in tests. Team members will integrate the devices in their military GN&C products. Litton will test one- and two-axis sensors and is targeting dual-use "iMEMS" insertions and interfaces with GN&C systems like GPS. Through cheap accuracy upgrades of its 2-gyro chips, the team predicts $100 GN&C sets for tactical weapons. DoD labs are testing device reliabilities and the team plans built-in self-testing for "iMEMS." Service users have deluged DARPA with sample requests and are learning to set requirements for application-specific devices. The team is working with MCNC on design and processing rules for "iMEMS" mask sets for multi-experiment chips. This gives MCNC's government and industry members access to ADI's production lines.

COMMERCIAL INTENT AND STATUS: The initial target is automotive navigation, followed by industrial robots, disc drives, computer/video-game joysticks and other electromechanical systems. *The team is marketing a 2-axis low-G accelerometer for simulators, plans several air-bag insertions of high-G devices, and is targeting IMU chips for car navigation and video games, as well as gyro chips for camera stabilization.*

Development of the Submerged Electric Drive Cargo Pumping System

Westinghouse, Electro-Mechanical Division (WEMD)

BACKGROUND: The reduction of Navy ship procurements has had major impacts on many defense industries. Westinghouse, Electro-Mechanical Division (WEMD) is an interesting example of such an industry. Until 1970, about 70% of WEMD's sales were commercial, but during the 1980's and 1990's defense became their primary market (65 to 70% of sales). Although there was a slight increase during the Reagan years, declining shipbuilding budgets resulted in business reductions at WEMD that resulted in a personnel reduction from 1,348 in 1992 down to 580 in 1995. The plan for this TRP project was to use WEMD's expertise in "canned motors," developed to a large extent in their defense business to address the commercial market. The objectives are to stay in business (and thus to continue to service the Navy's needs), and to pass on to the Navy any efficiencies and economies of scale derived from their increased commercial business.

OBJECTIVE AND GENERAL STATUS: WEMD is the sole supplier of the Navy's nuclear vessel reactor main coolant pumps. They have been in this business for 40 years. WEMD planned to develop a cargo pump for hazardous liquid (e.g., oil). Their approach was to convert the design of the military coolant pump to handle liquid cargo. The result was to be called the Submerged Electric Drive (SED) Cargo Pump. Unfortunately, the SED pump did not pan out commercially. Although it was certified by the American Bureau of Ships, the company decided that the commercial market, dominated by a long-term company, was too difficult. At that point, WEMD suggested that they be allowed to develop a SED Subsea Motor Pump Sub-system (SMPS) to address the need for a deep (1,000 foot) underwater oil pump.

MILITARY INTENT AND STATUS: All Naval nuclear vessels use WEMD coolant pumps. The key to WEMD's survival, given ever-decreasing Navy procurements, lies in the commercial market. This project presents an opportunity to accomplish this and, at the same time, continue to improve "canned motor" technologies used in Navy nuclear coolant pumps.

Some technologies being developed for this project may be of interest to the Navy. An example is the use of Titanium in the motor, reducing resistance considerably. On the whole, however, it is not likely that a direct transition will result from this project.

COMMERCIAL INTENT AND STATUS: *WEMD has formed a partnership with Petro-Leo Brasiliero S.A. (Petrobras), a Brazilian oil a 51% government owned Brazilian oil company engaged in subsea oil drilling (about 65% of their business). The pump that WEMD has developed is expected to allow greater than 1,000 foot depths to be accessed in a much more efficient manner than present systems. The consortium has formed a Joint Industry Program (JIP), which today includes Amoco, Chevron, Hardy Oil, and Oryx Energy. Interest from other oil companies exists and membership is expected to grow to 9 companies. The main benefit of the JIP, however, is a mechanism for marketing the product and for understanding the needs of the industry. At this time, commercial prospects look good.*

Development/Application of Advanced Dual Use Microwave Technologies For Wireless Communications And Sensors For IVHS Vehicles 1287

M/A-COM

BACKGROUND: New RF models and products in the cellular bands, with a premium on small size, and low operating voltages, and high efficiency for battery operated portable applications will serve the military as well as the commercial marketplace.

OBJECTIVE AND GENERAL STATUS: The purpose of this TRP was to develop and refine monolithic microwave integrated circuit (MMIC) component technologies in order to reduce unit costs and then to commercialize the items to further reduce costs. The military and commercial market impact will be in network sensors, oscillators, receiver subsystems, switching/signal control functions, and amplifiers in wireless, automotive "smart sensors" and medical applications. *The low-cost, ion-implanted MESFET process developed at the University of Illinois/Chicago was transferred to the MA-COM MMIC foundry. Successful developments that utilize GaAs MMICs were demonstrated for Wireless Systems, Intelligent Transportation Systems and Microwave Power Modules (MPM).*

MILITARY INTENT AND STATUS: A significant reduction in cost for a wide variety of microwave components will result from this activity. The military will also benefit from improved availability and supportability. *The MPM, which integrated a small traveling wave tube (TWT) with solid state components, proved to be so impressive that it has brought into question the DoD's promotion of all solid state approaches for RF power generation. The MPM is receiving serious consideration for use in the Navy's Cooperative Engagement Capability (CDC) program.* Other DoD programs that will benefit from this project are the Miniature Air-Launched Decoy (MALD) program and Vehicular Intercommunications System - Wireless (VIS-W).

COMMERCIAL INTENT AND STATUS: There is a rapidly growing market in 800MHz, 1.9GHz and 2.4GHz cellular and Personal Communication Systems (PCS). Monolithic microwave integrated circuit (MMIC) technology is ideally suited to help reduce the size and weight of these systems. Another area of important application for this technology is in Collision Avoidance Radar. *M/A-COM believes that approximately $100M worth of the product they sell has benefited from the technology advances that were made under this TRP project.*

Diffractive Optics Technology for Battlefield Management Systems 15002

Rochester Photonics Corporation (RPC)

BACKGROUND: Diffractive optics is a new technology that has high potential in emerging digital battlefield scenarios. To produce high-quality diffractive optical components, one must shape or "micro-machine" with nanometer precision the surface profile within each diffractive zone. Several recent methods have been used to fabricate surface-relief diffractive "master" elements. These master elements have, in turn, been used, with varying degree of success, to produce replicated prototype elements. Test results for optical systems employing diffractive elements are in excellent agreement with theoretical predictions. At present, the main impediment to wide-spread application of diffractive optics technology is cost.

OBJECTIVE AND GENERAL STATUS: The objective of this project is to develop low-cost manufacturing techniques and processes for the fabrication of precision, high performance optical systems employing diffractive optical components; to demonstrate the use of diffractive optics technology in prototype military systems such as head-mounted displays (HMDs) and electro-optic-sensor systems; and to develop novel optoelectronics that utilize diffractive optics technology. During the program, the team was to design, assemble, and evaluate the performance of diffractive optical systems in 8 different testbeds: an IR zoom-lens assembly for missile guidance systems; a full-color, liquid-crystal-based HMD; a multi-fiber transmitter array package; a cryogenic, focal-plane array readout assembly, an optical backplane assembly; a hybrid diffractive viewfinder for photographic cameras; a diffractive thermal weapon sight (TWS) and a reflective telescope; and optoelectronic modules for RF-photonics and communication systems. *Low cost diffractive microoptic fabrication was demonstrated by cast and cure replication; injection or compression molding and reactive ion etching (RIE) into substrates. While the nonrecurring costs of making asphere masters is between $5000 and $10000, the added cost of a cast and cure part is only $50 to $100, and plastic injection molded parts can be as low as $5 to $10. Along with the process development for low cost aspheres, work on scatter modeling from diamond machined surfaces; passive alignment of microoptic components; and design of full color, wide field off view HMDs with diffractive optical elements was progressing well. A first generation proof-of-concept package for multi-fiber transmitter arrays was completed in August 1997.*

MILITARY INTENT AND STATUS: This program will form a strong foundation that will enable cost and weight reduction of defense optical systems. Specific major defense programs for which diffractive optics assemblies could be critical include thermal weapon sights (TWS), Land Warrior Programs, shipboard and airborne infrared seek-and-track (IRST), Photonics Mast and Stinger Missile. *200 eyepieces have been delivered to the XXI Century Land Warrior program for incorporation in units being built in the preproduction phase. Scatter codes, developed on this TRP, are being utilized for the FLIR (forward looking infrared) system being developed for the A2GF Helicopter and are under evaluation for LRAS3 (long range acquisition system).*

COMMERCIAL INTENT AND STATUS: Commercial applications for diffractive optics include: optical pickup heads for data storage systems, consumer camera lenses and viewfinders, low-cost eyepieces and objectives for visible and near-infrared optical systems such as binoculars, telescopes, and rifle scopes. *The development of diffractive optic components has or will result in sales for the TRP consortium members in a number of commercial products areas. These areas include entertainment and toys, eyepieces (60,000 already marketed at $10 each) laser printing, advertising, counterfeit deterrence, optical data storage, laser projection displays, electronic imaging & inspection, automotive lighting, medical optics, virtual reality systems and bar code scanners. From these various areas RPC is now deriving 25% of its operating revenue; an*

increase from 0% before the TRP. Other consortium members have pending sales in the enumerated commercial product areas.

Digital X-Ray System for Trauma and Battlefield Applications 1142

General Electric (GE) Corporate Research and Development

BACKGROUND: This is one of two competitive TRP projects to develop a digital (filmless) x-ray imaging system for mobile trauma care units on the battlefield and for military and civilian hospitals. This system is based on solid state x-ray imaging panels which have been under development at GE for the past six years. The consortium consists of GE, one of the leading medical suppliers in the world, and EG&G, which supplies the detector to GE.

This will replace current x-ray systems entirely, although there is about 60% subcomponent commonality between GE's marketed (conventional film) x-ray and the digital prototype. The capital outlay for the digital machine will be higher initially, but GE claims that cost savings will provide a payback within about three years. This savings will accrue because film processing facilities will no longer be necessary and the hospital or clinic will be able to use the digital systems that are becoming common in health facilities.

OBJECTIVE AND GENERAL STATUS: The goal is to demonstrate the first chest-size imager system that replaces the x-ray film cassette with a solid state imager that directly outputs a digital image that can be transmitted over Ethernet. In approximately 25 seconds after exposure, the image is displayed on a monitor for view by a radiologist. The program will develop the technology to a manufacturable threshold.

The active area of the solid-state detector was 20cm by 20cm with a resolution of 1024 by 1024 picture elements. The final phase of the program has built and tested a full chest x-ray detector that is 40cm by 40cm with a resolution 2048 by 2048. The challenge was to make this detector on a larger substrate (50cm). To do this task, larger equipment was purchased and installed with the initial processing steps just beginning.

GE and EG&G are to introduce a commercial system in early 1999. Commercial prospects look very good. The TRP provided a four year acceleration of the development program. Originally the GE near-term goal was to concentrate on the smaller image market (cardiac/arterial imaging). The TRP provided development dollars in exchange for an agreement by GE to address the whole chest cavity x-ray challenge, which is what the military needs for battlefield triage and diagnostic purposes.

MILITARY INTENT AND STATUS: A digital x-ray imaging system for forward battlefield medical units and military hospitals that will save lives through rapid patient evaluation and consultation with physicians at a remote site (e.g., MEDFAST unit, forward of MASH units). The "Golden Hour," the first hour after injury is most important in saving a life. Gulf War records indicate that more than half of the casualties could have survived if the right equipment had been there at the right time. X-rays need to be available at battlefield level in order to: locate embedded shrapnel and bullets; identify collapsed lung or blood pool in the lung which could suffocate patient; look for broken bones penetrating vital organs. The improved dynamic range of the images reduce the number of x-rays (and radiation exposure) necessary. Digital imaging also allows immediate transmission of images from the battlefield to other sites, considerably reduces storage problems and eliminates the hazardous and difficult to transport chemicals affiliated with conventional photographic processing. The ability of trauma field units to diagnose patients at the

scene of injury rather than after relocation to the hospital and to store x-rays digitally in combat zones and transmit them to the patients destination is critical. It does not make sense to have surgical capability without ability to see into the patient. A coordinated, tri-service demonstration of a one-quarter-size digital director system was held in 1995.

Unfortunately, the link to the military deteriorated when DARPA moved out of telemedicine research, but it is clear that the military will eventually buy this system off-the-commercial-shelf. An evaluation of the system for mammography is planned for the National Medical Center in Washington, DC

COMMERCIAL INTENT AND STATUS: The commercial benefit is improved health care at lower cost. A digital x-ray capability at GE is estimated to increase projected market share for the year 2000. Mobile digital x-ray systems in emergency medical vehicles will allow on-the-spot diagnosis of internal injuries of accident victims. In hospitals, digital x-ray systems will mean an ability to immediately retrieve patient images and to consult among physicians worldwide by relaying x-ray pictures over the long distance by telemedicine communications. Storage requirements will be significantly reduced and loss or misplacement of photographs will be eliminated. Replacement of x-ray film with digital images will cost one-eighth as much as conventional x-rays resulting in a savings of up to $1.75 billion a year with this revolutionary imaging technology. According to GE, this will allow recoupment of capital investments in approximately 3 years in most cases. The current world market is about $3.5B annually. If they beat the competition, GE is projecting that their share of the market will increase to 39% by the year 2000. EG&G is in a different market altogether. Instead of selling equipment, they sell panels. The competition in diagnostic imaging is mostly foreign and includes Siemens, Thompson, Phillips, Hitachi and Toshiba. The primary domestic competition is the other TRP consortia team of Xerox and Varian.

According to GE management, investigative x-ray systems based on the new detector are currently being evaluated in clinical mammography and radiography trials at five U.S. hospitals with five additional testing sites planned. Systems using the new detector are currently limited to Massachusetts General Hospital, the Hospitals of the Universities of Massachusetts and Colorado, and the Hospital of the University of Pennsylvania. Additional mammography sites are planned for the University of South Florida.

Diver Alert and Tracking System 14016

Sonetech Corporation

BACKGROUND: Military divers need to know their precise location, but current approaches to that problem are rudimentary. Because a GPS signal cannot be received underwater, a different type of system is needed. Such a system would greatly enhance the mine location and clearance capability of the Navy's Explosive Ordnance Disposal and Special Warfare communities. Because such a navigation capability would also be of interest to sports divers and commercial diving operations, it should be sustained and enhanced by the non-DoD marketplace once this technology's feasibility is demonstrated.

OBJECTIVE AND GENERAL STATUS: This project was to develop and demonstrate a prototype Diver Alert and Tracking System that will produce navigation accuracy in the littoral, undersea environment comparable to differential GPS. *Two beta units, as proposed, have been completed and tested at the University of New Hampshire ocean engineering test facility. The units will next undergo sea trials.*

MILITARY INTENT AND STATUS: U.S. Navy Special Forces (SEALs) and law enforcement agencies have existing requirements for improved underwater diver navigation as well as underwater communications. Tentative Operational Requirements (TORs) also exist for technology that allows mapping of undersea mine fields by Navy divers in littoral waters. The completion and testing of the two beta units of the Diver Alert and Tracking System (DATS) will provide a proof of principle that equipment can be built that will take care of these needs. *ONR is presently considering a proposal to transition the Diver Alert and Tracing System (DATS) into Mine Counter Measure (MCM) and Shallow Water Autonomous Robotic Minehunting (SWARM).*

COMMERCIAL INTENT AND STATUS: Recreational diving is an upscale equipment oriented market. Divers already spend from $300 to $900 for dive computers. The DATS will become an addition to the dive computer that will greatly enhance the divers ability to know his location with respect to the dive boat as well as pass emergency signals between himself and the boat and/or other divers. DATS will also help the dive boat locate all the divers that it is responsible for. Market survey indicates that by the year 2000, 14,000 diver units and 2,000 boat units will be sold. *The sale of the first commercial units is being negotiated to provide security in the Sydney harbor during the year 2000 Olympics.*

Dual Use Hydrostatic Bearing Program 2739

Pratt & Whitney (division of United Technologies Corporation)

OBJECTIVE AND GENERAL STATUS: This project developed a hydrostatic bearing for rocket-engine turbopumps and industrial air-conditioner compressors that eliminates the traditional roller bearings that support the pump shaft. Instead, it uses the shaft's rotation to pump a small fraction of the working fluid (rocket fuel, refrigerant, etc.) under high pressure into the shaft/housing gap to create a thin film that centers and lubricates the shaft. Finding non-mechanical bearings is crucial for rocket turbopumps, among the most highly loaded machinery ever made. With roller bearings at the limits of current materials and designs, turbopumps cannot boost their power densities so as to cut payload delivery costs to space by an order of magnitude or more. The Air Force's Integrated High-Performance Rocket Propulsion Technology (IHPRPT) program is funding turbopumps whose performance requirements can be met only with hydrostatic bearings.

As these turbopump bearings would see only limited production, their designs need reliability and reduced-cost features best achieved by commercial mass market like air-conditioning compressors. The latter are being redesigned for "non-CFC" coolants that do not harm the earth's ozone layer but can be contaminated by traditional oil-lubricated compressor bearings. Yet across all applications, one issue is whether the working fluid in question can hydrostatically lubricate the shaft. For reusable launch vehicles, another challenge is finding bearing materials that tolerate transient unlubricated operation during startup and inflight stop-restart.

MILITARY AND COMMERCIAL INTENT AND STATUS: This project combined DoD needs in rocket turbopumps with Carrier Corporation's need for new bearings for air-conditioning compressor. Tests found that hydrostatic bearings could work with liquid-hydrogen propellant and non-CFC refrigerants. *Confirming the project's military value, the DoD focus moved from a bearing-rig test to insertion in two IHPRPT projects: an Integrated Powerhead Demonstration for a 250,000-pound-thrust first-stage engine and an Upper Stage Demonstration for a 50,000-pound-thrust rocket engine. Carrier successfully tested the bearing but chose lower-risk ceramic ball bearings for its new product line. The project's commercial niche now emphasizes turbopumps for commercial rockets. With massive growth in commercial satellite communication (satcom) networks outstripping DoD's foreseeable needs, commercial rocket builders are driven to cut rocket-launch costs to $1000/pound by boosting engine performance. Turbopumps with these bearings may enable medium-size rockets to lift heavy satellite payloads that now use costly heavy-lift rockets: a major benefit for both defense and commercial satellites.*

Dual Use Sensor Technology for Air Transportation System Capacity and Safety 1309

Lockheed Martin - OR & SS

BACKGROUND: The original TRP consortium was led by Martin Marrietta, a manufacturer of phased array radar systems for the U.S. Navy's AEGIS cruisers. Members included M/A-COM, a designer and manufacturer of T/R modules, General Electric Corporate Research and Development Center, an industry laboratory that participated in the initial research and development of phased array radar components; the National Center for Atmospheric Research, a federally funded research and development center improving aviation safety, capacity and efficiency; Rome Laboratory, a U.S. Air Force laboratory for surveillance technology; and Engineering Systems Design and Analysis Company, with expertise in the development of air traffic control automation functions. This project was conducted in Martin Marrietta's Moorestown, NJ plant. After the Lockheed/Martin Marrietta merger, the project was shifted to the Lockheed Martin plant at Syracuse, NY.

In a phased array radar system Transmit/Receive (T/R) modules electronically steer radar beams rather than using slow, rotating antenna dishes. The array also enables multifunction missions, such as weather sensing (e.g., storms and microbursts) and tracking non-cooperative targets (such as aircraft without transponders). In the array developed for this project, 550 of the 921 T/R modules are active, a "thinned out" array that saves cost. By thinning the array, the radar's side lobes are reduced, accordingly reducing out-of-main lobe effects. Both the military and commercial markets will demand cost reductions in T/R modules by more than ten-fold (from the current unit cost of $5,000 to around $300). Original system cost reductions can also be achieved through abandoning the concept of a four-face static 360 degree system in favor of a two-faced rotating system.

OBJECTIVE AND GENERAL STATUS: To accelerate the development of an advanced, multipurpose, S-Band phased array radar to simultaneously detect and disseminate flight hazardous weather conditions and local air traffic information.

By 1996 TRP funds were depleted. After the merger, the project was combined with a project to supply the rest of the system (e.g., the "back-end," signal processor computer and software, and displays). A demonstration was planned to test and evaluate the entire system. Beyond TRP, the Federal Aviation Agency (FAA) has provided some funding, which, combined with corporate money, has continued this effort, albeit at a fairly low level.

Component testing and an in-process demonstration in October 1997 revealed technical problems that are being addressed. Hopes for a robust, system-wide demonstration have been dimmed by these problems, lack of sufficient funding, and a electrical storm in May of 1998, which severely damaged the digital transmitters and receivers in the system. Instead, the FAA has requested the collection of weather data over the next few months that will be evaluated in a limited assessment of the radar system. Additional funding from the FAA seems doubtful, leading to a difficult decision on whether or not to continue.

MILITARY INTENT AND STATUS: The major impact will be in defense radar system affordability and multifunctionality, especially for the advanced systems. Although there will probably not be a distinct difference between the military and commercial versions, there could be some accommodation to the military, such as the development of circuits and formats to allow direct insertion of meteorological data into naval gun fire batteries. At this time, Lockheed Martin (GES) is developing dual-band T/R modules for use as a possible upgrade to the Navy's AEGIS system. In addition, the Navy is funding a study/demonstration to add weather-sensing capabilities to the AEGIS.

COMMERCIAL INTENT AND STATUS: The proposed system is designed to capitalize on the enormous Department of Defense investment in advanced radar technology to create a safer national airspace management system capable of significantly increasing the number of aircraft in operation around airports, detecting severe weather conditions to prevent fatalities. This is in response to a need stated by the FAA for a next generation air traffic control radar, called the Terminal Area Surveillance System (TASS). TASS requirements are thought to be well-addressed by the multipurpose dual use sensor., which also mitigates some siting problems exacerbated by the current need for multiple sensors.

A market of roughly $250 million per year is forecast by the end of the decade in air traffic control radar is the commercial target . The multi-tasking capability is particularly compelling for this sensor (e.g., weather). The resulting product is expected to be more costly than its commercial competitor (the ASR-9 and the TDWR), but each of these is a less capable radar. Further, capital and life cycle costs associated with buying and maintaining both of these competing radars (needed to fill all the roles the Dual Use Sensor would perform) may ultimately be more expensive.

E-Smart System for In-Situ Detection of Environmental Contaminants 5047

General Atomics

BACKGROUND: Over 30% of the DoD's cleanup costs for 4,000+ sites contaminated with EPA-regulated heavy metals and hydrocarbons, as well as similar Department of Energy (DoE) costs, now goes to wasteful, labor-intensive drilling, sampling and groundwater testing. Technicians must travel to sampling sites and send a manually collected sample off-site for lengthy (2-3 weeks) processing. Costs per sample may reach $1,000, yet over 90% of samples are "non-detects." Such sampling may not detect rapid environmental changes caused when low atmospheric pressure allows soil-entrapped gases or liquids to volatilize (barometric pumping). A lack of networking standards means that different vendors' sensors cannot cross-communicate or be retrofitted into existing networks but must operate as proprietary, non-networked sensors that require custom data links and display formats. DoD is tackling these issues through its open-architecture E-SMART (Environmental Systems Management, Analysis and Reporting NeTwork) standards for monitoring systems, accelerating commercialization of new sensor technology. Automated E-SMART networks can continuously monitor many sampling sites, using remotely calibrated sensors from multiple vendors. As E-SMART sensors are to operate unattended for years, the only manual activity needed is confirmatory sampling and verification.

OBJECTIVE: The team will develop a plug-and-play network combining (1) smart, in-situ multi-channel micro-sensors that use surface-acoustic wave (SAW) integrated-optics interferometry for high specificity and sensitivity and embed open-architecture E-SMART standards; (2) visualization software for real-time, remote-access data management and 3-D site mapping; (3) micro-controllers to standardize the sensors and network; (4) digital links for remote access; and (5) automated error correction for measurement accuracy. Beyond measuring environmental parameters (temperature, pH, hydrology, etc.), it can detect very low levels of water contaminants like BTEX ((benzene, toluene, ethylbenzene, xylene) hydrocarbon compounds, carbon tetrachloride, TCE, cadmium and chromium.

MILITARY INTENT AND STATUS: The team targeted DoD's Installation Restoration Program and Base Realignment Program. Troops can also deploy E-SMART networks as perimeter monitors for chemical and biological warfare agents (CWA, BWA). *The project has met its goals, including tests at Tinker AFB of a 23-node network, with the Air Force now DoD's major E-SMART advocate. The team is improving sensor durability, performance and producibility and is modifying its sensors for real-time CWA and BWA detection. The team formed an E-SMART Standards Organization (ESSO) with DoD approval to promote sensor-vendor collaboration on software compatibility and communications connectivity and to create a critical mass of vendors and users for E-SMART standards.*

COMMERCIAL INTENT AND STATUS: *The team formed ESSO to attract users but has not yet demonstrated the commercial viability of the prototype E-SMART network. It is working on 3rd-generation sensors, including BTEX sensors, and added a vendor to develop sensors for detecting heavy-metal groundwater contaminants regulated by RCRA (Resource Conservation and Recovery Act) on commercial sites.*

East/West Consortium: Next Generation Authoring Tools & Instructional Applications 2125

Apple Computer

BACKGROUND: A major concern in modern industrial societies is the development of better training and education technologies across all levels of education, from kindergarten and high school to professional education, military training, and job- or workplace-specific training. Across all these domains, educators and trainers find that retention of learning closely tracks the student's level of interaction with the course subject. This has led to training and educational simulation, model-building (constructionist) packages and increasingly interactive computer-based instruction (CBI) that allows personalized curricula for each CBI student. Yet the lack of standardization and common building-block software led to a "cottage industry" approach to CBI curricula that made it difficult to migrate innovative curricula to other users or other computer platforms. Meanwhile, the interactive development and instant distribution of CBI curricula allowed by the Internet, coupled with the growing power of personal computers, has transformed the CBI community by opening up interactive prototyping and testing of CBI curricula by online "virtual communities."

OBJECTIVE AND GENERAL STATUS: This situation created a need for easy-to-use, platform-independent, interoperable authoring tools that cut the cost of CBI curricula. When coupled with online "authoring communities" that work largely for free, these tools create not only a critical mass for CBI packages but also a set of de facto authoring standards and building-block software modules. This combination is very attractive to DoD and the services, who need training packages with more visual realism and virtual interactivity, portability and distributability through "distance learning," "just-in-time" or embedded training and rehearsal features, more mobility for use with wearable computers and displays, and greater inter-user connectivity for distributed simulation. The combination of tools and online authoring also allows small specialist groups in the services to create custom curricula cheaply and quickly. Prospective users include DoD's Undersecretary of Defense for Personnel and Readiness -- Director of Readiness and Training; service distance-learning and institute curricula, the Interservice Training Review Organization and the Joint Computer Based Instruction System.

This project tried to cut preparation for one hour of CBI curriculum from 100-1000 hours to 1 hour. It sought to commercialize JAVA-based CBI authoring tools for science and medical education from four universities and also to author educational and entertainment materials for two large publishers.

MILITARY AND COMMERCIAL INTENT AND STATUS: *The team soon realized the power of online authoring communities and reoriented the project to Internet distribution (vs. CD-ROM) of its curricula. This led it to adopt tools that can operate across multimedia environments and adapt to explosive growth in Internet-distributed software. The project succeeded overall. Falling short of its productivity goal (reaching 200-300 hours per course hour), is offset by the extraordinary efficiency of collaborative online authoring. The team created four start-up firms and numerous successful products. A direct spinoff is DoD's Advanced Distributed Learning (ADL) program, which promotes on-line authoring and Internet- or satellite-based "distance learning" for the services and defense agencies. DoD schools, from K-12 to specialized institutions, have adopted tools and services from this project. Another spinoff is the WorldBoard concept, which combines GPS-equipped wearable computers for location-cued data (e.g., battlefield terrain and elevation surveys, commercial site surveys) with wireless Internet, automated content filters, augmented-reality displays and touch interfaces. This allows all-mobile*

interactivity. WorldBoard derives from the EOE [Educational Object Economy] Foundation, an Apple Computer startup that promotes software "objects" (building blocks) for CBI authoring.

EcoScan - A Tunable IR Laser Remote Sensing System 1162

Boeing North America (formerly, Rockwell International Corp.)

OBJECTIVE AND GENERAL STATUS: Chemical warfare agent (CWA) threats against U.S. forces have spurred DoD development of laser-based lidar (light detection and ranging sensors) that can detect and characterize CWA plumes at multi-kilometer standoff ranges. DoD wants to provide enough time for troops, vehicles and ground facilities (e.g., command posts) in the plume's path to take protective measures (protective suits, sealing up vehicles, etc.). As CWA plumes naturally mix with other chemical aerosols, these lidars must identify and characterize the multiple chemicals in suspect plumes simultaneously and accurately. On the civilian side, similar needs exist for standoff chemical detection for controlling industrial processes to reduce emissions and to monitor such emissions for EPA compliance. The 1990 Clean Air Act Amendments (CAAA) require continuous near-real-time monitoring of chemical precursors for smog and ozone. One standoff lidar can monitor emissions from a wide array of industrial sources, making it cheaper than traditional "point detection" sensors fitted directly to (or in proximity to) stacks, valves and other emission sources.

This project emphasized a compact "differential absorption lidar" (DIAL) in the mid-infrared (IR) spectrum that can identify and quantify very low concentrations of multiple chemical species simultaneously from a one-kilometer standoff range. The lidar transmits two closely adjacent laser frequencies, then analyzes the gases' optical backscatter to determine the chemical composition of any gases in the laser path. Unlike non-DIAL designs, EcoScan needs no separately sited IR illuminating source or retroreflector, operating instead as a single mobile package. EcoScan's technologies included new frequency-conversion materials and a novel tunable solid-state laser for rapid detection, discrimination and distribution mapping of nerve gas and mustard gas plumes. Its solid-state laser and other parts also allow a mid-IR missile countermeasures (IRCM) device to protect aircraft from IR-guided anti-aircraft missiles by rapidly tuning the laser to the precise frequency of the incoming missile's optical-homing seeker.

As an early TRP project, EcoScan had a turbulent start and a change of corporate ownership but succeeded technically despite schedule slips and redirection from a dual use to a defense-only product. After contract award, Rockwell found that EcoScan's crucial technology (an optical parametric oscillator for rapid frequency conversion) was unavailable from its developer, a small start-up firm. In a rapid internal effort, Rockwell replaced it with a first-ever mid-IR laser with rapid electro-optic (EO) tunability, allowing programmable continuous tuning. By contrast, competing acousto-optic (AO) tuning offers more discrete bands but only sequential tuning. The brassboard lidar demonstrated excellent tuning control and accuracy at 250 Hz (hertz) over a range of 3.1 to 4.2 microns and consistently hit its intended wavelengths, detecting ethane and methane gases to parts-per-million sensitivity.

MILITARY AND COMMERCIAL INTENT AND STATUS: *At the project's September, 1996 end, the lidar did not meet the originally proposed size envelope (1x1x3 foot) and was behind schedule. However, Boeing (Rockwell's new owner) has extended EcoScan into long-wavelength IR for dual-band performance, with TRP-funded rapid tuning as its core. It will now market EcoScan for defense use only, including sensing of chemical signatures of nuclear and CWA proliferation. In the role of standoff sensing of CWAs and biological warfare agents (BWAs),*

DIAL lidars compete with more mature carbon dioxide lasers as well as with diode-pumped solid-state lasers, excimer lasers and frequency-converted lasers. Screening criteria for all such lidars include cost, complexity and performance on battlefields with very high signal clutter and signature masking.

Electric Variable Transmission 17013

Allison Transmission Division of General Motors Corporation

BACKGROUND: Military and commercial wheeled hybrid-electric vehicles (HEVs) are being designed with two independent (i.e., parallel) drivetrains: mechanical and electric. These are driven by one or both of two power sources: a low-emission, constant-speed diesel driving an electric motor/generator and a battery bank that provides burst power for hill-climbing, passing and acceleration from stops. The wheels are driven electrically (by wheel motors or transaxles) or mechanically (as in today's vehicles). The most attractive dual use option – a parallel-drive HEVs with mechanical wheel drive -- requires a transmission that is efficient in both power modes, separately or simultaneously. An "electric variable transmission" (EVT) in such HEVs can change output (and thus vehicle speed) while the engine runs efficiently at constant speed. It offers the low noise, high efficiency and high power density for volume of electric drive; sustained speed on steep grades through combined battery and diesel power; elimination of engine overheating; high power across the speed/torque curve; and low emissions in intermittent-duty, stop-and-go urban trucks. It is scaleable from Hummer jeeps up to 50,000-pound tracked vehicles and heavy trucks and accepts one-mode (transmission speed range) or higher mode designs.

OBJECTIVE: This project stresses a two-mode EVT scaleable to 40,000-pound commercial stop-and-go trucks and 20,000-pound military trucks. It seeks to improve exhaust emissions by 10% - 20% and fuel economy by 16%, while retaining vehicle performance matching or exceeding that of conventional engine/transmission drivetrains.

MILITARY INTENT AND STATUS: Wheeled HEVs with EVT offer low acoustic and thermal signatures and 20-mile range for stealthy battery-only operations on the battlefield, high mobility and high fuel efficiency. The team is stressing two key performance parameters for acceleration and grade climbing. While targeted at 2-5-ton trucks, it can also drive 25-ton tracked vehicles, attracting Amy Tank Automotive Command interest as an option for future HEVs like the Future Infantry Fighting Vehicle and Future Scout Cavalry System. Other Army uses include scout and "Hummer" vehicles and all-wheel-drive heavy trucks, which are largely similar to their commercial counterparts. Allison has supplied 100,000+ transmissions for wheeled Army vehicles and sees annual replacement rates up to 5,000 units, with combined DoD and commercial sales passing 10,000 in 2004 and 50,000 in 2006. EVT's high dual-use commonality in components means that high commercial volumes can carry most military productization costs. *The EVT is in powered testing as a next-generation transmission under Allison's product-development strategy.*

COMMERCIAL INTENT AND STATUS: EVT's targets include fire and garbage trucks, buses and heavy delivery trucks in emission-controlled cities. Low-emission EVT fleets do not need alternative fuels and engines and their new support infrastructure. An EVT with engine and motor/generator fits most trucks, allowing fast conversion. In trucking, drivetrains must last 15-20 years, memories of poor products linger long and acceptance of new products is slow, due to increased infrastructure and capital equipment costs. Allison is teamed with major truck and engine vendors, assuring "end-user" pull from most major truck and bus producers worldwide. *Allison*

sees AVT as its next-generation heavy-truck transmission and will use its vast distributor and service network to encourage truckers to buy the EVT as standard equipment.

Electron Bombarded CCD Camera 14018

Intevac Advanced Technology Division

BACKGROUND: Night vision capability is a critical defense technology, and heretofore has primarily been used by the military in limited applications and quantities.

OBJECTIVE AND GENERAL STATUS: This project was to develop and prototype an Electron Bombarded Charged Coupled Device (EBCCD) camera that will have two times better resolution at low light levels, ten times greater sensitivity, half the package size, and a lower cost than existing Image Intensified night vision I^2CCD cameras. *EBCCD cameras with performance equivalent to I^2CCD cameras and a 2X size reduction have been produced. The limitation on performance has been shown to be the 10 year old electronics, originally designed for I^2CCD cameras. New read-out electronics is being fabricated to demonstrate the true capability of the EBCCD.*

MILITARY INTENT AND STATUS: The EBCCD camera will develop an expanded night imaging capability advantageous to the military users. The performance improvements will allow recognition and identification at greater ranges and under lower light level conditions than presently possible under existing technology. This will enable improved surveillance capability for night time urban or forest/jungle operations. In addition, the smaller size and lower cost of this device will allow it to be used in many more operational situations than current devices, including as a subsystem in surveillance platforms. *Even though the expected performance has not been achieved, the EBCCD camera has generated interest at the Air Force Air Borne Laser programs and 7 cameras are being provided to them for evaluation under a Lockheed Martin subcontract. The EBCCD technology is also being applied to the Air Force ERASER program. Intevac is under contract to supply an EBCCD camera to Raytheon for this program. The EBCCD technology is also being examined for use in next generation Star Trackers for the Trident Missile.*

COMMERCIAL INTENT AND STATUS: The lower cost sensors will also allow broader use by non-military users such as the federal, state and local law enforcement agencies as well as private security communities for general targeting and surveillance applications. Uses also exist in commercial medical, microscopy and spectroscopy applications. All these applications will provide a way for DoD to obtain and sustain this technology at a lower cost. *The 2X reduced size that has so far been achieved has already generated interest from the FBI. Also the reduced complexity of the EBCCD leads to modeling that predicts that the cost of the EBCCD camera will be less by a factor of two when it gets into production.*

Electronically Controlled Variable Displacement Vane Pump 1024

Coltec Industries-Chandler Evans

BACKGROUND: The standard fuel pump for the commercial and military aviation gas turbine industry, has been the single-element, fixed-displacement, gear pump whose inlet is charged with a centrifugal boost stage. This configuration, as part of the overall engine control system, is relatively heavy and lacks versatility. However, it has proven to be extremely durable in millions of hours of service on numerous applications. In addition to supplying metered fuel flow to the engine, the system must also absorb waste heat from the engine lubrication system and the aircraft avionics. This is especially true with the large commercial transport engines and many large military engine applications. In the current technology, the fixed-displacement gear pump is designed to meet the highest flow condition while most of its operation is at far lower rates of flow, resulting in significant thermal inefficiency. The current technology compensates for this inefficiency by incorporating supplementary coolers which rob airflow from the engine fan. Another second significant characteristic of the conventional technology is the need to integrate the pump and the fuel control into a complete system.

The technology development under this program is a pumping system which can vary the amount of fuel delivered according to engine needs, thereby limiting the resulting fuel temperature rise. This permits the elimination of the air/oil coolers and conserves the vital airflow through the fan. The variable displacement vane pump (VDVP) also permits a substantial simplification of the control system with the elimination of complex metering valves, reducing fuel system cost.

OBJECTIVE AND GENERAL STATUS: The objective of this project is to develop variable displacement vane pumps of various sizes having the durability of current gear pumps but without the temperature and flow control limitations. These devices also have a fuel metering capability that will deliver the precise amount of fuel to maximize engine performance. This effort was intended to only go through the endurance testing phase only. Projected cost savings range form 20 to 60% and weight savings range from 36 to 87 pounds or from 40 to 50%.

MILITARY INTENT AND STATUS: *The Propulsion Directorate of the Air Force Research Laboratory has begun a follow-on program to develop VDVP.*

COMMERCIAL INTENT AND STATUS: The VDVP technology development effort is expected to provide a very efficient and durable fuel pump for commercial aircraft. The potential commercial market is estimated at $300 million. Chandler Evans feels that there is very high potential for commercialization in all classes and sizes of aircraft due to the cost savings and weight savings potential.

Two test units have been sold, one to GE and one to NASA. Chandler Evans currently has an internal program to establish reliability of > 2000 test hrs./year (two yr. program). In addition, Allied Signal has conducted successful tests on a small version that has potential application on their 731, a small business aircraft. In general, it is expected that the VDVP will be market ready by the year 2001.

Experimental SONET OC-192 (10 Gb/s) and ATM Self-Healing Ring

Belcore

BACKGROUND: This TRP effort was an attempt to join with the commercial sector to develop a broadband infrastructure capable of transmitting and receiving information at 10 Gigabit per second (Gb/s). The resulting infrastructure will help to develop SONET (Synchronous Optical Network), a new and growing body of international standards that defines all aspects of transporting and managing digital traffic over fiber optic facilities in the public network. Conforming to SONET will ensure networks interoperability and seamless data transmission. ATM (Asynchronous Transfer Mode) will facilitate broadband multimedia services necessary for simultaneous transmission of voice, imagery and other digital data. A self-healing feature, being developed under the program, will enhance network survivability. This technology is critical to developing the National Information Infrastructure.

OBJECTIVE AND GENERAL STATUS: The objective is to develop and test a 10 gigabit per second, self-healing fiber optic transmission system called Synchronous Optical Network (SONET). The system will reduce network complexity and cost, increase network efficiency, and permit high-capacity data throughput. A self-healing ring network can survive network node failures or optical fiber cuts, permitting computer networks to automatically operate around a failed network node. *Even though no complete, commercial 10Gb/s systems were developed under the project, this work has been incorporated into U.S. and international standards documentation in accordance with which several commercial vendors, such as Lucent Technology, Nortel Telcom, and Fujitsu, are building SONET OC-192 systems. The success of establishing the standards will assure the consortium partners sales for their sub-systems, and enable interoperability of products among different suppliers. In addition, testing methodology and instrumentation as well as subsystem components were developed.*

MILITARY INTENT AND STATUS: This project will create an environment for the DoD to experiment with the management of high bandwidth networks and to leverage on the commercial investment. SONET presents significant benefits to the Global Grid concept of the DoD. The increasing needs in intelligence, surveillance, communications, and command and control functions will require handling a high volume of traffic, and it is assumed that additional capacity will have to be borrowed from the public networks. The large capacity of SONET is required to meet both the long term and surge requirements of defense needs. The DoD will benefit from this program by being able to purchase 10 Gb/s data links or leasing time on such networks from the commercial telecommunications providers. *The technology and product have been used indirectly by DoD. SONET OC-192 systems have been deployed by long distance service providers in the U.S. since 1997. They are used mainly in high traffic routes across North America, in particular the Internet backbones of major long distance vendors. Some of these services are being leased by DoD users NSA and DISA.*

COMMERCIAL INTENT AND STATUS: The SONET market is one of the fastest growing sectors of the U.S. telecommunications systems, with an estimated annual growth rate of 30% per year through the year 2000. This TRP development will permit major inroads into this rapidly expanding and internationally important market. Using advances made under this TRP in application specific integrated circuit (ASIC) design, it will be possible to obtain significant reductions in size, weight, and cost of SONET equipment. *Individually, consortium members successfully developed subsystems: Rockwell achieved 10 Gb/s gallium arsenide heterojunction bipolar transistor (HBT) integrated circuits (ICs), Tektronix achieved the necessary electronic*

subsystems, and Lucent developed the optical end to end subsystems. Bellcore is still working on complete system integration.

Extrapolation of Adaptive Optics Technology to the Manufacture of Electronics and Next Generation Information Display Systems 3149

AOI International

BACKGROUND: This effort was led by a small company that manufactures equipment for the production of printed circuit boards. During the course of the project, the company ran short of funding and the development had to be stopped. Fortunately, the company was able to regroup and, due to the flexibility of the Other Transaction Agreement, they were able to resume the effort at no additional cost to the government. They eventually completed the prototype instrument development.

OBJECTIVE AND GENERAL STATUS: The project's goal was to transition real time adaptive optics wavefront sensing technology developed from military surveillance applications to the commercial manufacturing arena, specifically providing dynamic control of image quality in high volume vision inspection systems, as well as, supporting the manufacturing of ultra fine-line printed circuit boards and solid flat-panel displays. *A prototype instrument that meets all but the positional accuracy specifications was built.*

MILITARY INTENT AND STATUS: The commercial product from this development effort will permit the manufacturing of ultra-fine precision printed circuit boards and will lower the cost of military liquid crystal heads-up displays by facilitating inspection as each layer is processed. *No product has yet been produced.*

COMMERCIAL INTENT AND STATUS: The enhanced high volume vision inspection systems to be manufactured will incorporate technology critical to measure minute variations. The successful completion of this effort will drive inspection costs down and, at the same time, increase yields for large printed circuit boards and flat panel displays. *Even though a prototype instrument was built, commercialization of the instrument remains on the companies' long term business plan, no specific time frame for producing a marketable instrument has been set at this time.*

Field-Deployable, Continuous Monitoring Mass Spectrometer 5078

Teledyne Brown Engineering

OBJECTIVE AND GENERAL STATUS: Defense against chemical and biological warfare agents (CWAs, BWAs) demands both standoff and point-detection sensors to detect and characterize CWA/BWA plumes. As a "direct sensing" method, mass spectrometry (MS) allows highly accurate point detection of such aerosols. An MS device accelerates a sampled aerosol particle across a measuring space containing a fixed deflection force. It infers the particle's mass and composition by measuring its deflection along its flight path to an impact site. By comparing its deflection with a library of similar data for other chemical and biological materials, an MS device can identify the sample. Because they often use bulky gas-chromatography (GC) "front ends" to filter and characterize new samples, thereby allowing more efficient spectroscopy, MS devices have been too large for portable use. But despite this sizing and complexity problem, the

versatility of MS sensors lets them tap a growing commercial market in monitoring industrial emissions of all kinds. This impels developers to compact, highly reliable and affordable MS sensors for wide industrial use.

This project sought to design, develop, test and commercialize a field-deployable MS for continuous monitoring that would build on Teledyne's commercial Discovery 2 quadrupole-MS unit, an affordable and highly sensitive ion-trap design. The sensor was to target volatile organic compounds (VOCs), PCBs (polychlorinated biphenyls), heavy metals and explosives in subsurface soil and water, surface water, solid waste piles and liquid- and solid-phase industrial processes. It would have used a new direct-injection sampler coupled to an affordable, highly sensitive commercial ion-trap MS unit. Phase 1 goals emphasized CWA sensing in a lightweight, durable self-contained device, with weight reduction as a main goal. The team planned to accelerate regulatory approval of the instrument by federal and state environmental regulators, an approval central to the unit's commercial salability in environmental monitoring markets.

MILITARY AND COMMERCIAL INTENT AND STATUS: *This project was a failure. Although Teledyne was poised to build prototypes, had reached most of its goals and had found strong government and commercial interest in the sensor, it halted the project in late 1997 for business reasons with no advance notice to DARPA, the Army or its TRP partners. It refused to disclose the sensor's status or its plans for the residual hardware. The disposition of the sensor and remaining project funds is unclear at this point.*

Fly-By-Light Advanced Systems Hardware (FLASH) Program 3081

Boeing (formerly, McDonnell Douglas)

OBJECTIVE AND GENERAL STATUS: To improve aircraft survivability and save weight, aircraft designers have long sought to replace hydraulic power with electrical or electromechanical power in the flight-control system (FCS) that links pilot control motions with aircraft control surfaces (ailerons, trim tabs, rudders). They would complement this shift to "power-by-wire" (PBW) by replacing traditional mechanical and hydraulic control signals with "fly-by-wire" (FBW) electrical signals or "fly-by-light" (FBL) optical signals. FBW is used in some modern FCS. FBL is rated as riskier but offers higher payoff. Combining PBW with FBW/FBL is especially useful for military aircraft, whose loss in combat or peacetime accidents often is caused by damaged hydaulics, and for commercial airliners. The FLASH project combined FBL with PBW to maximize performance and weight reduction, with flight-testing set for military helicopters, fighters and C-17 airlifters.

Compared to conventional FCS, FLASH yields lower life-cycle costs, immunity to EMI (electromagnetic interference), better maintainability and weight savings of up to 6,000 pounds on large aircraft. It is projected to reduce vulnerability by 14% while boosting reliability by 10% and maintainability by 12%. FLASH technologies include electrohydrostatic actuators (EHA), sensors, fiber-optic cables and optical/electronic transducers that convert optical signals to electrically driven control-surface movements (and vice versa). As optoelectronics have not been used before in safety-critical functions, FLASH components must be highly reliable, maintainable, producible and affordable, while offering plug-and-play commonality and connectivity. This entails advances in quality control standards and lifetime testing, manufacturing and installation techniques.

MILITARY AND COMMERCIAL INTENT AND STATUS: The FLASH team planned to develop and flight-test FBL/PBW FCS components, including an EHA, to qualify them for use on

military and commercial aircraft. The team's goal is early flight qualification of FLASH components, which for commercial airliners allows FLASH retrofitting on test aircraft. Transition candidates for FLASH include the Joint Strike Fighter (JSF), the F-22 (which will use some fiber-optics) and remanufactured or rebuilt AV-8B, F-15, F-18 and AH-64 aircraft. Personnel from the F-22 and JSF program offices are involved in the FLASH project. The project ties in to a TRP project called VITAL (Vehicle Management System Integration Technology for Affordable Life Cycle Cost), which is developing interface standards and manufacturing methods for FBL, FBW and PBW components for use in remanufactured or new-build AH-64, F-15, F-18 and AV-8B aircraft. PBW-driven EHA and all-electric actuators are also being built and tested under the Air Force's "More Electric aircraft" (MEA) program.

The project ended in September, 1996 after demonstrating low-cost cabling (including connectors, splices, test equipment and processes); a smart actuator that uses neural-net self-diagnostics and a low-cost receiver; and a high-horsepower EHA for fighters and commercial airliners. The project verified the performance of FBL sensors, protocols and interfaces for the AH-64, a fighter and a MD-90. The latter made a first-ever January, 1998 flight of an optically controlled control surface. FLASH EHAs have transitioned to JSF, which seeks to cut maintenance by replacing hydraulic actuators. Other components have transitioned to VITAL, a NASA satellite, the NASA/Lockheed Martin X-33 reusable launch vehicle; and USAF's MEA program. Boeing's purchase of McDonnell-Douglas Aircraft (McD), the #3 maker of commercial transports, has complicated FLASH's commercialization prospects and timelines. McD had seen FLASH and VITAL providing a competitive edge over Boeing (#1) and Airbus (#2). Boeing now appears committed to both projects or their follow-ons. However, when and if FLASH or VITAL FCS will be offered as retrofits or for new-builds of current aircraft is uncertain as of this writing..

Gamma Ray Imaging System for Nuclear Environment Monitor 3079

AIL Systems, Inc.

BACKGROUND: A two-dimensional Gamma Ray Imaging System (GRIS), commercially named the GammaCam, was to be developed to assist in locating, detecting and mapping (in 2 dimensions) radioactive materials in environmental clean-up activities and power plants. GRIS will also be useful in the investigation of nuclear smuggling operations. Unlike existing detection systems which can only "point" at the location of radioactive materials, this imaging system will allow sources emitting gamma rays to be viewed on TV-like monitors to determine their location, size, and intensity with great precision.

OBJECTIVE AND GENERAL STATUS: The objective of this TRP project was to develop gamma ray imaging technologies and employ these technologies in a portable, affordable, rugged, reliable, two dimensional gamma ray camera capable of monitoring nuclear radiation environments. Development activities included the integration of advanced detection and signal processing technologies and the design, fabrication, and evaluation of a prototype detector. The gamma camera developed under this project is unique in its capability to instantly provide a visual depiction of the location and strength of gamma radiation sources with color-coded images superimposed on a black-and white television image of the scene in the camera's field of view. The camera is lightweight as a consequence of not requiring any shielding. The TV monitor is remote from the camera thus avoiding the need for personnel to be in the radioactive environment. The ability to image weak sources of radiation in the presence of sources an order of magnitude stronger is a unique and important feature of the GammaCam. Also its ability to rapidly determine

the spatial location of invisible, buried sources of radiation contamination is an important aid in radioactive contamination clean-up efforts.

MILITARY INTENT AND STATUS: This dual use technology development effort benefits both the U.S. Department of Defense and the U.S. Department of Energy with a heretofore unavailable gamma ray camera for enforcing nonproliferation of nuclear materials, treaty verification, and environmental restoration operations. *AIL developed a state-of- the-art instrument for the decontamination and decommissioning of nuclear facilities and the management of nuclear waste. One unit was sold to Los Alamos National Laboratory (LANL) and another one to the Idaho National Engineering and Environmental Laboratory. One of these unit is being used for NEST (Nuclear Emergency Search Team) applications. AIL has also responded to various solicitations that may result in the Services acquiring these units. The Navy is considering the possibilities of using this camera in the maintenance, operation, and building of nuclear powered ships and submarines. The Army at Ft. Monmouth, has been involved in discussions of using the camera for aerial photography and the Army Corps of Engineers is considering leasing the equipment for a cost benefit analysis of deactivating a CP-5 Reactor at Argonne. In addition, AIL has responded to an Army BAA to use this technology in counter terrorism and anti-terrorism operations. AIL has found a parallel interest in the Ministry of Defense in the United Kingdom as a result of demonstrations conducted in the UK during the fall of 1996. AIL is expecting orders from various users in the defense organizations of the UK.*

COMMERCIAL INTENT AND STATUS: The GammaCam can also be used by commercial nuclear industries to cost effectively manage and operate nuclear facilities with improved ALARA (As Low As Reasonably Achievable) objectives. *AIL has been marketing the gamma camera, under the trade name of GammaCam™, globally since 1996. The product has received outstanding user response since its introduction to the commercial marketplace. Sales and leasing of GammaCam™ to the commercial nuclear power industry, decontamination and decommissioning operations, and nuclear waste management have been initiated. British Nuclear Fuels Limited is in negotiations for 6 units for their nuclear waste sorting plants and AIL has proposals out for another 9 units.*

Gas Generator Fire Suppression 17012

Kidde Technologies, Inc.

BACKGROUND: Since the adoption of the Montreal Protocol by the United States, various efforts have been undertaken by the government and industry to identify suitable fire suppression alternatives to Halon. It is desirable to have fire suppression alternatives that are environmentally friendly, while competitive with Halon in operational and performance characteristics (e.g., efficiency, price, ease of storage). In particular, the aviation industry requires a fire suppression system with size and weight equal to or less than those of current Halon systems.

OBJECTIVE AND GENERAL STATUS: In this project, Walter Kidde Aerospace, Atlantic Research Corporation and the government joined together to develop two fire suppression systems that would incorporate propellants that are effective alternatives to Halon. The Pyrotechnically Augmented Liquid Agent System (PALAS) is designed for use in spaces such as military crew compartments and industrial explosion suppression, while the Chemically Active Solid Propellant Gas Generator (CSPGG) is designed for use in spaces such as military and civilian aircraft engine nacelles and dry bays. Currently, several propellants have been characterized as to their suitability

for the approaches with ongoing small-scale fire suppression testing of the chemically active propellant mixtures and liquid agents.

MILITARY INTENT AND STATUS: *Both systems were developed to fill military needs. They were first tested in the military environment. Testing was performed on the WPAFB F-22 Engine Nacelle Simulator, an F-22 Dry Bay Fire Simulator, and an M-113 Armored Personnel Carrier, during an Army Tank-Automotive Command Crew Bay Live Fire Test Series conducted at Aberdeen Proving Ground. All tests went well, demonstrating the technical feasibility of the PALAS and CSPGG systems. Further testing has been recommended by the consortium. Meetings with the F-22 System Project Office are planned to pursue insertion opportunities for PALAS. The consortium also under consideration for an Army Tank/Automotive Command contract to conduct further testing and evaluation of crew bay PALAS fire suppression devices -- decision due in mid-1999. Part of the problem is the cost of certifying this approach to replace HALON systems.*

COMMERCIAL INTENT AND STATUS: *Commercial sales are uncertain at this time. However, for some applications, such as the aviation industry, strict size and weight requirements for the fire suppression system may lead to the adoption of this technology. Automotive fire suppression testing has been performed successfully in the engine compartment of a 1984 Chevrolet Celebrity at the National Institute of Standards and Technology in Gaithersburg, MD. The consortium intends to pursue the automotive market in both the commercial and military sectors.*

High Capacity Solid Polymer Battery Development 3249

Lockheed Missiles & Space Company, Inc.

OBJECTIVE AND GENERAL STATUS: The objective is to develop and demonstrate Lithium Ion battery technology with a polymeric matrix. Unlike the SAFT, Inc. effort, these batteries will be rectangular cells and more advanced technologically. SAFT will initially be cheaper, but, eventually, this approach may be more affordable. This is higher risk and potentially a higher payoff. This TRP project has just been completed successfully, with commercial sales and projected military sales.

MILITARY INTENT AND STATUS: The anticipated outcome is smaller, lighter, and less expensive batteries for replacing NiCd, Silver-zinc and Nickel-hydrogen for most military applications. Batteries are a significant percentage of consumables used on the battlefield. Today's batteries are heavy and, not generally rechargeable, or are rechargeable over a limited number of cycles. Their replacement by long-life, rechargeable batteries would be a considerable boon to field units, in terms of logistical re-supply, carrying weight, and O&M costs. If this effort is successful, the increased performance (versus NiCad and other Li Ion batteries) will be a major payoff for the military. Additionally, there are important logistical advantages in packaging rectangular shapes. High capacity solid polymer electrolyte batteries using lithium ion solid polymer electrolyte cells will serve military applications, such as man-portable electronics power supplies, unmanned underwater vehicles, and launch vehicles.

Much battery power is wasted with non-rechargeable batteries, since soldiers often replace slightly-used batteries before missions. The Army has decided that, beginning in 1998, training will be conducted with rechargeable batteries.

This technology is being developed as a replacement for the current portable BB590 Battery which is a Ni Cad. This battery is currently used in the SINGARS and MILSTAR radios. The solid polymer batteries would achieve a weight reduction of 40% over the current BB590. Additional DoD applications of this technology include underwater and space vehicles. Lockheed Martin is also considering using a solid polymer battery as a replacement for the current D5 battery on the Trident Missile. This program has also made advances in fast charging for these cells. An attribute considered to be essential for the eventual application of this technology.

COMMERCIAL INTENT AND STATUS: *10,000 batteries have been sold. Ultralife is producing commercial batteries on an automated assembly line and selling them to lap-top computer manufacturers. Eagle Pitcher is now marketing the battery.*

High Power High Temperature Superconductor (HTS) Technology Development 1081

COM DEV, Ltd.

BACKGROUND: High Temperature Superconductivity (HTS) provides a new technological opportunity for obtaining electronic devices and functions that far exceed the characteristics of conventional components. The challenge is to consistently control the composition of the materials and to provide reliable, cost effective cooling to below 77K.

OBJECTIVE AND GENERAL STATUS: The purpose of this TRP activity was to develop high power, high temperature superconductor (HTS) microwave components for satellite applications. The emphasis of this program was on novel microwave circuits that would lead to miniaturization of high power components. *Neither military sales nor commercial sales have yet occurred at the sub-system level. Subsystem component for both military and commercial applications have been successfully tested and sales are expected in CY 99.*

MILITARY INTENT AND STATUS: HTS technology provides a 10X to 100X improvement in overall microwave systems performance, primarily due to improved filter and resonator parameters. It is expected that 10% of the $30-50 billion market for defense microwave hardware could benefit from HTS technology by the year 2001. Systems that will benefit from the HTS developments on this program include MILSATCOM, military, anti-jamming GPS, over-the-horizon-radar, radars in littoral waters, SINGARS, B-1 interoperability, and Have Quick. The cryogenic cooler development will also apply to many cooled infrared imaging systems in development by the Services.

COMMERCIAL INTENT AND STATUS: The earliest applications foreseen to benefit from HTS technology are in the commercial communications satellite systems where miniaturization of equipment has a very significant impact on cost. The commercial satellite market for communications, remote sensing and space science is expected to be in the $4-5 billion per year range in the 1995-2005 time frame; at the same time period the global superconductor market is expected to grow from the current $1.5 billion to $8-12 billion by the year 2000 of which the electronic portion is estimated to be between 25-40%

High Temperature Distributed Control Systems 10015

United Technologies Research Center (UTRC)

BACKGROUND: Distributed control architectures offer better performance and reliability, lower weight, and lower purchase and maintenance costs. This project will allow distributed architectures to be more widely used in both military and commercial applications by improving the ability to place smart sensors and actuators in hostile, high temperature environments.

OBJECTIVE AND GENERAL STATUS: This project was to develop and demonstrate affordable, reliable, distributed control systems with electronic modules that operate up to 200° C. In particular, this project was to demonstrate high temperature, distributed control components on a F119 jet engine vane actuator and a compact, integrated multi-horsepower motor. *The consortium has successfully developed 17 integrated circuits (ICs) in silicon-on-insulator (SOI) technology, 16 of which are characterized as "known good die" that function at 200 C and one has been tested in a high temperature package. From these, an integrated clock generator and three multi-chip-modules (MCMs) for the distributed engine control application have been built. Two of the MCMs have been tested for functionality. One, the power supply, is fully functional from room temperature to 200 C, while the analog/digital/input/output (ADIO) MCM has a problem that is under study. Parker, a consortium member, will be integrating the complete control module into a smart actuator that will than be incorporated into a Pratt & Whitney technology demonstration engine, the XTE-66-1, to be tested in the Dec. 1998 to Jan 1999 time period. The power converter for the smart motor has also been built, but has not been integrated into the motor yet.*

MILITARY INTENT AND STATUS: A study on the benefits of distributed control showed that in the case of the V-22 tilt rotor aircraft, 244 lbs of weight, 50% VMS life-cycle costs, 40% of the electronic procurement costs, and 65% in maintenance man hours per flight hour could be saved. Similar impact is expected on the costs of the High Performance Turbine Engine Technology used on the F-119, contemplated for the JST as well as other PW4000 derivatives. *Dependent on the outcome of on going tests, both the F-119 and JSF engines may be configured for distributed control.*

COMMERCIAL INTENT AND STATUS: In industrial motor control systems there is a pervasive paradigm shift when centralized control systems are replaced by distributed high performance controllers. This trend tends to integrate control logic with power electronics. This places the control electronics in a harsh temperature environment requiring high temperature electronics. Similar modules are needed for automobile ignition controls, anti-locking brake system solenoid controls, electric power steering, and smart motor systems. *Honeywell, a consortium member, has generated data sheets for most of the high temperature circuits developed and expects to make deliveries to commercial customers by the end of 1998. In conjunction with the high temperature IC development, an enhanced software package has been developed to accurately predict reliability of components at high temperatures and when being cycled over large temperature excursions. The consortium is presently looking for a software house to commercialize this product. The commercial market appears soft and thus sales are presently questionable in the area of smart motors with integrated power converters, where the true advantage is compactness. However, the consortium has brought in Ford Motor Company, Caterpillar and Cummins, who all are interested in adding these motors to their commercial products when the cost becomes acceptable to them.*

Hybrid Propulsion Development Program (HDPD: formerly, Hybrid Technology Option Project (HyTOP)) 3612

Lockheed Martin Corporation

BACKGROUND: Current expendable launch vehicles (ELVs) are fueled either by liquid propellants, with oxidizer and fuel in separate tanks, or by solid propellants, in which under current practices the oxidizer is mixed with the fuel. However, the latter practice converts the solid propellant into a high explosive whose accidental detonation on the ground, at launch or in flight can cause fatalities and demolish ground facilities. Solid-rocket motors (SRMs) are built up by stacking segments in an operation that must be protected from severe shocks, stray voltage or other ignition sources. At launch, current SRM fuels produce toxic plumes, like the shuttle's hydrochloric-acid plumes, making wind direction a launch factor for populated coastal launch sites. Rocket builders thus have sought hybrid SRMs, which pump a liquid oxidizer down through ports in the upper end of the motor's solid-fuel block to combust in the motor's core. As the pump rate controls thrust, the motor can stop and start in flight, a feat impossible in current SRMs. Both propellants can be nontoxic and inert, allowing SRM segments to be poured, shipped and handled as inert industrial commodities, at major cost savings.

This project builds on pioneering work by American Rocket Co. (Amroc) on 250,000-pound-thrust hybrids. Amroc successfully test-fired a motor segment but encountered major unknowns (oxidizer porting, controlled fuel recession to protect casing walls, throttleability, etc.). Supported by NASA-MSFC's "solid propellant integrity program" and "laboratory scale solid rocket combustion simulator" program, Amroc teamed with SRM vendors and integrators (Lockheed Martin, Thiokol, Pratt & Whitney, Rockwell International's Rocketdyne subsidiary, and Boeing) to develop such data under TRP. Amroc's subsequent bankruptcy left Lockheed Martin as the team leader.

OBJECTIVE: The team seeks to build a "first principles" hybrid performance database that allows scaleable motor designs. It focuses on two markets: small motors for sounding rockets, an early-return market allowing design verification and production, and large (250,000-pound-thrust) SRM boosters (SRBs) for commercial and military ELVs. The SRBs would fit the size envelope of a conventional solid motor of similar thrust but would be 20%-30% cheaper and would be serviceable on the pad.

MILITARY INTENT AND STATUS: Hybrid SRMs make ELV operations cheaper, safer, more reliable and environmentally cleaner. Being inert, hybrid tactical missiles stowed in shipboard magazines cannot be detonated by exploding nearby missiles (sympathetic explosion), unlike shock-vulnerable conventionally fueled missiles. *The project has been a solid technical success, although no military transition was planned, given the "first principles" nature of the project. Technical papers have been given to the JANNAF (Joint Army, Navy, NASA, Air Force) steering committee for rocket propulsion R&D.*

COMMERCIAL INTENT AND STATUS: Hybrid motors greatly reduce handling, transportation and launch costs. This is important in the sounding-rocket market, where the launch cost of conventionally fueled rockets (up to $1 million) is largely driven by the costly safety documentation and design specifications required for such fuels.

The project was a solid technical success, developing a firm engineering database. The team built two large motors for medium-size ELVs, with a successful test firing at NASA's Stennis Space Center. Lockheed also test-fired over 250 sounding-rocket motors and is now offering them for sale to sounding-rocket integrators. Commercial ELV programs (Lockheed's Athena and General

Dynamics' Atlas) have sought price quotes and technical data. Lockheed proposes an Atlas 2-AR(H) variant using this project's SRMs. Lockheed is also working on other spinoff components that reduce the complexity, cost and weight of medium-lift SRMs and smaller vehicles while improving their safety.

HyperEducation Consortium 5026

Enterprise Computing Institute (ECI)

BACKGROUND: The U.S. economy is directly dependent on a flexible, highly skilled workforce. This project developed technology that bears directly upon this issue. To that end, this project has developed ongoing collaborations with the Department of Labor, the Office of Science and Technology Policy (Dr. Henry Kelly), the National Guard and the Undersecretary of Defense for Personal Readiness (Mr. Don Johnson). Accomplishments have also been briefed to Vice President Gore. The significant interest in this TRP project is engendered by the fact that U.S. industry lags behind in its ability to use new technology. Improved avenues of training are expected to significantly improve this situation.

OBJECTIVE AND GENERAL STATUS: The participants in the Hypereducation Consortia planed to develop and demonstrate tools to allow educators to easily create interactive learning materials, lessons, applications, course and curricula targeted for access through the Internet. As part of the work plan, the participants were to develop open standards for electronic lesson "formats" and the methods for creating and retrieving them. During the TRP project, several pilot lessons were to be formulated to demonstrate the capability and to provide examples for other lesson writers. *While the demonstration goals were achieved, it was discovered that the real problem was the availability of training via the Internet and thus the program had to change its focus. The reoriented project uses most of the developed software and addresses the training development problem. Early demonstrations showed that by using repositories of reusable training components to construct training products for delivery via the Internet it was possible to decrease the development time from weeks/months to minutes in the production of customized training.*

MILITARY INTENT AND STATUS: The ability to quickly create and disseminate teaching and training materials are essential in the dynamic training environment of the military and should result in significant savings in time costs. *The utilization of the products of this TRP project by the military will come via developments in the private sector. However, discussions are ongoing towards the development of a CRADA agreement with the National Imaging and Mapping Agency to develop and deploy training in geospatial imaging technology using the TRP developed technology and infrastructure.*

COMMERCIAL INTENT AND STATUS: This TRP project will open up the education and training market to a large number of electronic providers and has the potential to revolutionize the way people learn and teach, leading to a capability for quick creation and adaptation of lesson material and the ability to access this lesson material via the Internet. *The technology is just coming to the market place. This project has been continued with additional supplementary funding from the Department of Labor (DoL)/Employment and Training Administration and grants from the Commonwealth of Massachusetts. DoL added $700K in FY 1998 and is expected to add millions of dollars in FY 1999.*

IMAS: An Intelligent Modular-Array System for the Monitoring of VOCs in the Environment 5055

Sawtek, Inc.

BACKGROUND: This project pursues surface-acoustic-wave (SAW) sensors and smart networks for detecting chemical environmental contaminants and warfare agents (CWAs). The SAW sensors are small, cheap, selective, extremely sensitive, robustly tolerant of minimally processed samples, and versatile in accommodating widely varying chemistries, air and water media, and aerosol particle sizes. They can be digitally linked with non-SAW sensors in a network that offers plug-and-play compatibility with chemical environmental sensors – or point- and standoff-detection CWA sensors -- of different detection methods. SAW devices can be given various polymer coatings for detecting specific gases or liquids. In addition to detecting mixes of contaminants, the multi-element IMAS arrays also calibrate and trouble-shoot themselves to ensure accurate measurements. Such embedded self-calibration and diagnostics eliminates labor-intensive maintenance visits to IMAS sites.

OBJECTIVE: The team plans a versatile, low-cost network of smart SAW sensors for rapid site characterization and process monitoring of volatile organic compounds (VOCs) in air, water and soil. DoD uses include base monitoring and CWA detection. The palm-size modules offer integral sampling, sensing, analysis, and data management. They report their data through a TRP-funded E-SMART (environmental systems management, analysis and reporting network) communications network whose DoD-endorsed standards are designed to accelerate the commercialization of new sensor technologies.

MILITARY INTENT AND STATUS: IMAS sensors allow real-time detection of chemical spills and effluents on military bases and reduce base-cleanup costs by eliminating offsite/offline analysis. They can also be given various polymer coatings for sensitive point detection of specific CWAs and biological warfare agents (BWAs) in gas or liquid forms, while using E-SMART interfaces to access battlefield CWA/BWA-sensing networks. Environmental sensors are rarely purchased directly as discrete end-items by military or commercial users. Rather, users buy them embedded in larger sensor networks or environmental-monitoring service agreements from commercial providers. Military transition of IMAS sensors thus will come as they are integrated by other vendors on a mix-and-match basis with other networked sensors into a specific defense network or architecture like the Joint Chemical Agent Detector (JCAD). *The project is meeting its goals, which in the near term are tied to the Air Force-managed E-SMART TRP project. Two vendors are proposing SAW/IMAS devices for CWA sensing.*

COMMERCIAL INTENT AND STATUS: The team targets companies affected by laws for air and groundwater chemical pollution, seeing temperature-compensated SAW/IMAS superior to other SAW designs for such monitoring. IMAS/SAW can be used in other commercial and defense uses. *The team has not yet sold IMAS commercially but finds chemical-industry interest in environmental monitoring and federal interest in monitoring site remediation.*

In-situ Process Control for Growth of InP-Based Heterostructure Materials For Gigahertz Circuits 2126

Raytheon (Hughes Research Laboratories)

BACKGROUND: Indium-Phosphide (InP) is a compound semiconductor. Because of its electronic properties, devices fabricated from it or its lattice-matched ternary alloys have better characteristics in some applications than those fabricated from the more commonly available semiconductors. Progress in InP has been limited due to the expense and difficulties associated with achieving well controlled epitaxial layers by prevalent growth techniques. If successful, this TRP project will support a technology critical to defense needs and commercial economic growth with the development of a U.S. based infrastructure in compound semiconductor growth equipment, materials and devices.

OBJECTIVE AND GENERAL STATUS: The goal of this TRP project was the simultaneous sensing and control of both doping and composition in the production of heterostructure thin films on InP for high performance electronic circuits. This may result in unique materials, produced in larger volumes at higher yields and lower cost than the material that is presently grown by molecular beam epitaxy (MBE). This effort will enable competitive organizations to acquire modest quantities of leading-edge InP-based custom electronics components at affordable prices by increasing the availability and reducing the costs of heterostructure substrates.

MILITARY INTENT AND STATUS: Higher performance electronic materials produced in larger volumes at high yields and low costs would result in a significant benefit to a wide spectrum of military electronic capabilities, impacting such areas as electronic warfare, guided missiles, spacecraft, communications, command and control, and many others. *EMCOR, a partner in the consortium, has become a U.S. foundry for compound semiconductor material. Presently, they are a qualified second source for InP-based materials for which there exist but a small, mainly government market, but the same foundry produces GaAs-based material at a rate of 1000 to 1500 wafers per month. No military utilization of this technology has yet occurred.*

COMMERCIAL INTENT AND STATUS: The capability to produce InP-based heterostructure material to specification and qualify it in situ during growth, obviating the need for post-manufacture testing, will raise yield and thereby lower its selling price. Unless the technology is developed, it will be difficult for the U.S. to remain competitive in the world marketplace for compound semiconductor materials. *A collaboration between two of the consortium members, Woollam, a manufacturer of elipsometers, and Emcor, the manufacturer of metal-organic chemical vapor deposition (MO-CVD) systems, has resulted in an elipsometer and software, specifically designed for achieving reproducibility and reliability for materials grown in a MO-CVD system. The MO-CVD system with this software will be the first commercial product from this project. A prototype machine is in existence and EMCOR is in the process of engineering a second generation system for which three customers have expressed an interest*.

Industry Common Building Block Electronic Modules 10014

Lockheed Martin Control Systems

BACKGROUND: Common building block electronic modules (CBBs) could significantly lower the design, development, manufacturing and long term maintenance cost (electronic part obsolescence, etc.) of electronic systems for both military and industrial applications. This TRP

project will facilitate the development of low cost CBBs by employing Multichip Encapsulated Flex (MCM E/F) packaging technology. The CBBs utilizing commodity die will provide a high density/cost effective alternative to low volume, higher cost custom circuits (ASICs, etc.).

OBJECTIVE AND GENERAL STATUS: The purpose of this project is to develop common building block electronic modules (CBBs) that can be shared by U.S. manufacturers for jet engine control systems, aircraft flight control systems and in applications by other industries such as automotive, industrial automation, process control and locomotion. An additional goal is to extend the maximum temperature limit of the MCM-E/F process to allow realistic design choices for advanced distributed control systems (greater than 200º C). Specifically, goals of the TRP was to design, fabricate & test a family of "reusable" CBBs that can be transitioned to a wide range of existing and future control systems for both military and commercial applications. *The high temperature (>200 ºC) needs have been partially met by fabricating a test module with high temperature circuit die, but the adhesives used in the MCM process are limited to 150º C. Several adhesives were identified that should work, but funding issues stopped the effort. "Reusable" CBBs were developed for a dual torque motor driver, a dual solenoid/relay driver, linear variable differential transducer (LVDT) signal conditioner, a multiplexed A/D interface, a speed interface, and a thermocouple / variable resistance transducer (TC/VRT) interface. The designs are all completed and in various stages of MCM fabrication. A production foundry for the MCM-E/F (Chip on Flex) process has been installed and is fully operational at Lockheed Martin Government Electronics Systems (LMGES), Moorsetown, NJ.*

MILITARY INTENT AND STATUS: It was expected that the proposed technology will be matured in time for JAST, ASTOL, Army Challenger Program and other future military engine programs. *This program has developed an "insertion module" for the electronics of the F414's Full Authority Digital Engine Control (FADEC) that would replace the existing electronics with two types of CBBs. This insertion module's performance will be demonstrated in a production F414's FADEC over the full temperature environment required.*

COMMERCIAL INTENT AND STATUS: It was expected that the proposed new approach will reduce the cost of a typical jet engine controller by 20-40%. A significant reduction in maintenance costs is also expected. If only aircraft engine applications are considered, using an estimated production of 750 engines/year (for 225 aircraft) over the next 15 years the life cycle cost (LCC) reduction directly attributable to the utilization of common electronic modules was expected to be over $1 billion. *The 6 CBB MCMs developed under this TRP project will provide all requirements anticipated for performing the engine control functions of both General Electric Aircraft Engines and Allied Signal Engines. LMGES plans on selling components made with MCM-E/F (Chip-on-Flex) process to both military and commercial customers. The chip-on-flex process has cost advantages over existing industry multichip module packaging approaches. To date there are no commercial sales.*

Integrated Opto-Electronic Modules (IOEM) 2681

Lucent Technology

BACKGROUND: Optical interconnections, using fibers and discrete electro-optical devices, is common today for long distance communications and data. Copper cables are being replaced by

fiber optics in order to reduce cross talk and noise, and increase bandwidth. A transceiver element function converts electrical signals to optical signals at both ends of the data link. This is now accomplished by using discrete electro-optical components at high cost and large size. However, it is possible to integrate all these components into a monolithic Integrated Opto-Electronic Module (IOEM). A IOEM transceiver will reduce cost when it is produced at high volumes. This TRP consortium was formed to achieve such an IOEM.

OBJECTIVE AND GENERAL STATUS: The goal of this project is to expedite the development of high density, reliable, rugged and low cost optical and electronic components on a common substrate forming a monolithic Integrated Opto-Electronic Module (IOEM). The components include switches, multiplexers, beam splitters, amplifiers, analog-to-digital converters (ADC) and wave guides. The targeted IOEM is a low cost device which translates electrical signals into light pulses on optical fibers. The primary problem with mass producing fiber optic gyroscopes is the need to precisely align the light source, a small laser, with the optical fiber. The telecommunications industry has the same problem when setting up new fiber optic transmission networks. But civilian applications of this technology need not meet the rugged performance requirements of the military, nor do they need to be miniaturized. This project has encouraged the consideration of military requirements in commercial technology developments so that national security needs are addressed in a cost effective and timely fashion. Success demands the ability to manufacture the laser and the fiber connector on the same "chip," (substrate), thus solving the alignment problem. *This TRP project has developed a low cost IOEM.*

MILITARY INTENT AND STATUS: In its quest for more precise delivery systems, the military has mounted TV cameras, laser seekers, and infra-red devices in the noses of so-called precision guided munitions and missiles, to making sophisticated terrain guidance and satellite systems the brains for cruise missiles. All of this has been too expensive for more mundane munitions such as iron bombs and artillery shells. Technology is providing some new solutions to help make "lower tech" munitions smarter in an affordable way. One approach features devices called fiber optic gyroscopes (FOG), a device which is able to detect very small changes in position by reading the fluctuations in light waves traveling around a bundle of glass fibers. To make this technology affordable for the military, it is necessary to achieve a cheap source for simpler devices which may be mass produced. *The military will first use the IOEM module in a low cost Fiber Optic Gyro (FOG), made by Fibersense Technology. They won an Army contract to replace the mechanical gyros in the Bradley Fighting Vehicle with the smaller, lighter weight FOG. At current replacement rates, the Army will save $120K per year (reflecting a savings of $400 per unit). If all 6,500 Bradleys are so equipped, the eventual savings will be nearly $3M. Fibersense also joined Allied Signal in a major Navy guided munitions program that will deliver 300 FOGs during the development phase. If successful, the follow-on work will be a combined Navy/Army program delivering between 10,000 and 100,000 FOGs at a saving of $400 per unit over alternatives; potential savings of $40M to the DoD.*

COMMERCIAL INTENT AND STATUS: A major civilian application for IEOMs is to link commercial fiber optic cables into homes with standard metal wires, a market area known as Fiber-To-The-Home (FTTH). *This TRP project aided Lucent in developing this technology to the point that they were able to negotiate a $6B joint development program with NTT to complete adaptation of their IOEM for fiber-to-the-home (FTTH) markets in Japan -- not only opening Japanese markets to Lucent, but also encouraging interest among domestic network providers.*

Integrated Small Precision Optics Manufacturing Technology 15004

Rockwell International Corporation

BACKGROUND: The program has three distinct parts: micro-optics, micro-opto-electromechanical (MOEM) devices as scanners, and narrow band filters for chemical spectral sensors. Micro-optics often replace spherical optic elements, while micro-scanners and narrow-band spectral sensors, have potential military utility and market potential to implement small scale automated adaptive systems capable of auto focusing and ranging, barcode readers, driver situational awareness enhancers, medical printers, and as wavelength discriminators for chemical sensors for automobile emission control as well as battlefield chemical warfare sensors.

OBJECTIVE AND GENERAL STATUS: To develop and integrate manufacturing technologies for small precision optics. This was to include micro-optics, thin films, micro-opto-electromechanical (MOEM) devices as scanners and narrow band filters for chemical spectral sensors. These were to be used in small scale automated adaptive systems capable of auto focusing, ranging, wavelength discrimination, scanning imaging and projection. The consortium was to demonstrate the applicability of these optical sub-systems in two key military products: missile warning receivers and very low cost helmet-mounted displays. Product feasibility demonstrations were also to be carried out for five additional dual use products: automobile emission sensors, self-contained auto focus units, barcode scanners, color sensors and driver situational awareness enhancement. *At this time the micro-optics part is furthest along as it has provided quad lenses that have been successfully tested for missile launch warning and tracking, and micro-lenses are being incorporated by Polaroid into its line of commercial laser products. Preliminary microscan devices have also been demonstrated.*

MILITARY INTENT AND STATUS: Very small, lightweight scanners and microoptics can be used for aircraft crew head-mounted displays (HMDs) that can effect military systems worth hundreds of millions of dollars. Similarly, compact wavelength-selective devices will allow the development of laser threat warning receivers, optical identification friend-or-foe (IFF), multi-wavelength imaging missile seekers, wavelength agile laser radar/FLIR systems and remote battlefield chemical sensors. *Quad IR microlenses have been successfully tested at White Sands as missile warning sensors.*

COMMERCIAL INTENT AND STATUS: The same microptic technology can be used for small integrated scanner modules for simplified HDMs for the entertainment industry or for small 1-D and 2-D barcode scanners, both of which are billion dollar industries. Wave length selectivity will be important in the automotive industry for on-board emission sensors that satisfy federally mandated air quality standards, specific chemical sensors for industrial applications and automated process control such as used in color monitoring for pharmaceutical sorting and packaging. *Polaroid has incorporated microlenses into their commercial laser configuration and has sold over 400 such lasers. Micro-scanner technology is being pursued for productization by three consortium members: Allan-Bradley is field testing a barcode reader for use as a low-cost compact hand-held scanner; Polaroid is developing a medical printer head with an autofocus engine that will be in production in 1998; and Ford Motor Co. is evaluating a rear vision system as a back-up or parking aid as well as a blind spot eliminator. Mid-wave infrared (MWIR) wedge spectral filters have been demonstrated as gasoline sensors, and MWIR and long-wave infrared (LWIR) filters have been used to demonstrate remote sensing of chemicals.*

Interoperability Testbed For Diagnostic and Prognostic Maintenance of Equipment and Processes 5035

Pennsylvania State Univ., Applied Research Lab (ARL)

BACKGROUND: The combination of smart multi-domain sensor networks with electronic commerce (EC) transactions and high-bandwidth "National Information Infrastructure" (NII) networks like the Internet promises a revolution in remote "health monitoring" (HM) and maintenance and diagnosis (M&D) of gas and steam turbines (and related generators, heat exchangers, boilers and auxiliary machinery) used in aircraft, ships, electric utilities, industrial plants, pumping stations and other facilities. Such NII-aided remote HM/M&D allows automated trend analysis and predictive trend forecasting for condition-based maintenance (CBM) and optimized turbine operation for extended life. It gives the turbine/platform operator access to the latest diagnostic software and HM tools from specialty M&D vendors as an outsourcing alternative to owning and using such tools directly. It also meshes with technology trends in automated M&D reasoning and neural networks, low-cost distance links and embedded processors. In military use, aircraft engine anomalies and other data collected on inflight recorders could be remoted to M&D service providers for comparison with similar engines, yielding faster, higher-confidence advice to forward maintainers. This concept also appeals to the utility industry, where deregulation rewards lowest-cost power generators and drives utilities to extract more operating efficiency and life from aging machinery.

OBJECTIVE: Using a powerplant testbed operated by the Electric Power Research Institute (EPRI), the team will diagnose engine vibrations for the Navy's E-2C Hawkeye radar plane and will also develop remote EC-transacted HM and prognostics services over the Internet for on-demand predictive and condition-based maintenance of utility turbines. For the latter, an outside HM/M&D vendor can use the Internet to obtain a digital model of the equipment in question or build it from legacy information. The vendor could alert the plant's owner to potential failures and enable him to develop maintenance schedules or work-arounds that optimize the plant's operation. The testbed will integrate EPRI's utility network and ARL's network technology with smart information-retrieval tools. For both users, the project will yield interoperability standards and conformance testing tools for Internet-aided HM/M&D.

MILITARY INTENT AND STATUS: DoD's HM/M&D needs will rise steadily with longer-life military equipment. DoD-operated or DoD-accessible global networks allows on-demand tele-HM/M&D of forward-deployed aircraft, ships and other turbine-powered systems. Automated M&D functions can be hosted on the turbine or its platform or remoted to M&D sites hosting larger data fields or more advanced analysis tools. Beyond the E-2, the team will open its testbed to other platforms with digital engine-data recorders: e.g., the Navy/Marine Corps V-22 tilt-rotor transport; the SH-60 helicopter; F-16, F-15E and F-117 fighters; the C-17 airlifter; the Navy/Marine Corps LCAC (Landing Craft Air Cushion); Navy ship-propulsion gas and steam turbines; and the Army's M-1 tank. Yet off-loading or remoting HM/M&D functions to outside M&D vendors through distance links is a radical shift from the services' traditional practice of on-site/inhouse HM/M&D.

The team met its goals. The remote-HM/M&D testbed has attracted interest from other Navy programs (e.g, F/A-18 and F-14) and contractors (e.g., Allison Aircraft Engine Corporation (E-2C engines) and General Electric's Aircraft Engine Division. While the project focused on turbines, its technology permits M&D on most mechanical systems that can be equipped with sensors and data loggers. This allows monitoring of turbine engine parts (gearboxes, blades and disks, combustion section liners) and use of prognostics and detailed part knowledge for

operational planning and maintenance scheduling. The Navy is assessing project results for monitoring ship propulsion plants. The team also received Air Force queries for aircraft engine diagnostics and identified Army and Marine Corps programs that can use the technology. ARL will also bid the project's technology for a Navy CBM project for helicopter diagnostics.

COMMERCIAL INTENT AND STATUS: Air-pollution laws, deregulation and the decade-long lead times needed for new baseline generation capacity are driving utilities to advanced HM/M&D to maximize turbine life and cut operating costs. This prompted EPRI's testbed in the early 1990s. *EPRI and ARL have collaborated to form a spinoff company to market the project's technology to its members for monitoring powerplants and related utility infrastructure.*

ISMIS (Intelligent Shock Mitigation and Isolation System) Through Applied RSPM Technology 10005

Enidine

BACKGROUND: Protecting shock-sensitive electronics and mechanical systems of nuclear submarines and surface ships from underwater explosions is crucial as the Navy moves to greater shipboard use of COTS (commercial-off-the-shelf) equipment not designed to military shock standards. Both underwater blasts and earthquakes produce combined shocks: a high initial shock followed by random vibrations. The Navy now uses all-passive shock mitigation: e.g., resilient mounts, electro-hydraulic dampers and putting machinery on "rafts" isolated from decks, bulkheads and hull. Such hardware inherently is "tuned" to certain frequencies or shock levels and cannot manage combined shocks. Competing "active" shock mitigation for ships and buildings uses large, high-response electro-mechanical or hydraulic actuators that demand continuous electric power. Combat damage to shipboard electrical power or earthquakes damage to a building's electrical power render "active-protection" actuators useless. The common behavior of underwater explosions and earthquakes allows a dual-use solution -- semi-active "reactive structural parameter modification" (RSPM) -- to emerge from seismic-protection markets. RSMP offers "active" performance on battery power alone. Combining simple hydraulic servo dampers and sensors with robust algorithms, it intelligently tailors the mass response, damping and stiffness of a ship or building to combined shock. It outperforms active systems and reduces ship and building response to shock loads by 50%-60% and 50%-70%, respectively, over all-passive methods. Its real-time "learning" of building behavior means that minimal structural data is needed to determine actuator mounting points.

OBJECTIVE: This project extends RSPM from seismic protection to shock protection and acoustic silencing for the New Attack Submarine (NSSN).

MILITARY INTENT AND STATUS: By using commercial markets to cut Navy ISMIS hardware costs, the Navy can buy modestly hardened COTS electronics and housings for its ships and use ISMIS/RSPM to fully harden them. The Navy seeks three-fold shock reduction over passive systems. *The project met its Navy goals, with highly successful underwater blast tests of ISMIS hardware on a subscale submarine hull. The team is also discussing surface-ship ISMIS use with the Navy and Newport News Shipbuilding.* It is targeting ISMIS for one NSSN but Navy acoustic-silencing guidelines pose additional problems. The Navy sponsor has concerns about ISMIS' complexity for shipboard use. ISMIS can also protect defense facilities like command posts, airbase control towers, weapon storage depots and other critical sites where continuity of military operations is crucial.

COMMERCIAL INTENT AND STATUS: The initial ISMIS market is seismic protection for select high-value structures. *The team is testing a quarter-scale system on a University of Buffalo shake table. Full-scale actuator hardware is in development and the team plans to fit ISMIS to a complete building at a California university*.

Just-In-Time Maintenance 2444

Northrup Grumman Corporation

BACKGROUND: Structural failure of rotating machinery is catastrophic in some critical applications such as helicopter rotors and critical cooling pumps in nuclear reactors. The current approach is preventive replacement, a practice which reduces service life and wastes manpower. Grumman Data Systems Corporation, a traditional defense contractor, joined with Long Island Lighting Company, a major New York utility, and Texas A&M University, to build and test a prototype system to detect faults in rotating machinery before failure.

OBJECTIVE AND GENERAL STATUS: The objective of this project is to build and test a prototype system to detect faults in rotating machinery before failure so that they can be replaced just before required and not on some necessarily conservative preventive schedule.

MILITARY INTENT AND STATUS: Cost savings in operation of military helicopters resulting from longer, safer mean time between scheduled maintenance as well as from catastrophic failure avoidance. *Unfortunately, there does not seem to be sufficient interest in the Army for this application and insertion may have failed.*

COMMERCIAL INTENT AND STATUS: The size of the U.S. market is estimated at $293 million in 1993 with an 8% annual growth rate. Of this, $45 million is vibration analysis software. Significant penetration of this market is anticipated. The system has been tested on railroad wheel bearings and is currently being employed to monitor several types of machinery at the TBG Cogen Power Generating Plant. Once fully developed, the technology would be licensed by Northrop-Grumman for embedding into existing commercial and defense machinery monitoring systems that are available from respected diagnostic industry vendors. The approach of "Just-In-Time Maintenance" implies taking a piece of equipment off-line for servicing when required, rather than according to a fixed schedule. This approach also has the capability to detect incipient faults before failure which is highly desirable for critical or high dollar value equipment.

During the project, the system successfully picked up the vibrational anomolies resulting from progressive damage to three different carbo-blowers operating at a Long Island Lighting Company (LILCO) power station in New York. Later, a damaged railroad wheel bearing was identified and classified by the neural net and compared with data from the Association of American Railroads. The analysis was achieved with a success rate of over 96%.

Unfortunately, the program has been thwarted by a disruption of key technical personnel, facilities, resources, management support, and corporate cost share during two mergers of acquisitions of the original consortium. The consortium is trying to find new members and continue its effort to address the commercial market. If this works out, the project can still be a commercial success. Although the project is not currently being funded by the industry, there is still hope that the system will eventually be commercialized.

LEGOS: Object-based Software Components for Mission-Critical Systems 5088

I-Kinetics, Inc.

BACKGROUND: I-Kinetics and its partners were to develop an array of reusable software components and services adhering to the emerging Object Management Group's (OMG) technology standards. Key innovations to be included were the capacity for software component composition and synthesis, tools for collaborating with legacy (existing) software, object management services for fault-tolerant systems and team-based workflow automation.

OBJECTIVE AND GENERAL STATUS: The major thrust of the consortium's effort was to advance current Common Object Request Broker Architecture (CORBA) technology by advances in six specific technical objectives: dynamic synthesis of object interfaces, automated component interface generation, components for efficient communication and coordination for groups of objects, achieve a reliable object management service, establish a virtual data warehouse, and integrate and automate workflow. A key result of this TRP effort is the concept of reusable software architectures. Software architectures enable components reuse. A programmer cannot develop a software component to meet reuse requirements unless those requirements are defined. A software architecture, which describes the mechanisms by which components interact and gives common patterns of components interactions, provides such requirements. A second important contribution is the notion that a software architecture is something that can be captured in a formal language and reused across multiple applications. *In this effort, the Unified Modeling Language (UML), that is fast becoming the industry standard, was used to prototype architectures of military weapons systems. The innovation of the software component factory is facilitating the realization of components software for multiple reuse. The factory approach takes advantage of emerging standards such as UML, CORBA, Java and the Internet. The major technical innovation of the software components factory is the ability to assemble and test new systems configurations as well as assemble new tools on demand from existing tools and architecture design repositories. The key was to transform legacy data and applications into components. These components could then be combined in a domain-specific basis to design military software systems architectures.*

MILITARY INTENT AND STATUS: NAVSEA was to host the development and deployment of a demonstration-scale logistics planning and management system for ship maintenance, a demonstration of full workflow integration for critical NAVSEA executive program management information systems. *Now the products of this project are in use at 400 sites, including the Air Force Phillips Laboratories, the Naval Sea Command, the Naval Ordinance for an ordinance management system, Rome Laboratories in their Imaging Laboratory, and DoD systems houses such as TRW and Lockheed. TRW uses it in their Nuclear Readiness Management System. Large benefits are being derived from the ability to extend the life of DoD's existing software systems by making use of the technology developed under this TRP project.*

COMMERCIAL INTENT AND STATUS: The commercial demonstration was to be a concurrent engineering program to be developed and deployed by Pratt & Whitney Government, Engines and Space Propulsion. *The consortium used the TRP project to improve their software products: IONA, the current CORBA market leader, extended their CORBA product, Orbix(R), with high-performance transaction management, object groups and fault-tolerant services; NetLinks Technologies built a new generation of ORBitize^{TM}; I-Kinetics advanced the development of their component software such as the DataBroker®, ObjectPump® and Automated Component Generator (ComponentFactory®). The ObjectPump transforms, at run-time, a legacy application or data source into a Component. A software standard evolved that*

became commercially viable in the timeframe of the TRP. The revenues for both IONA's and I-Kinetics grew significantly. IONA's growth was from $2M to $90M; TRP provided 5% of its R&D funds for that period, so conceivably around $4.5M of that growth may be attributed to the TRP. I-Kinetics' revenues grew from $0 to $4M, while the TRP contributed 25% of their research, thus possibly generating $1M of that revenue.

Lithium Ion Rechargeable Battery Development and Deployment 1380

SAFT R&D Center

BACKGROUND: Saft, America, Inc. is a battery supplier for the DoD. After Desert Storm, DoD battery sales went down, presenting a grim financial situation to Saft, who decided that they had to address the commercial market to survive. Saft has worked on Li ion battery technology for 2 to 3 years because it is rechargeable, has a high specific energy compared to nickel cadmium (NiCd), is safe, is environmentally sound, is potentially less expensive than NiCd, and has a long life (>1,000 cycles).

OBJECTIVE AND GENERAL STATUS: This project focused on manufacturing and "intelligent charging" of LiON® batteries which normally do not charge uniformly if cells are at different charge status. Intelligent charging was proven feasible in this project -- it requires a special chip. Saft was starting with a good electrolyte, manufacturing process and proprietary technology. There was also an intent to establish a commercial manufacturing line, producing rechargeable lithium ion 18650 cells, at SAFT's military oriented Lithium Battery Division at Valdese, N.C. *The successful development of the 18650 cell and the necessary control electronics was completed within the 2 year time frame.*

MILITARY INTENT AND STATUS: The military has been burdened with high recurring costs for throw away primary batteries and implementing LiON® rechargeable technology in military batteries offers a clear pathway to reduce costs. The Army's Communications and Electronics Command (CECOM) is part of this team. Saft will deliver 100 small batteries (radios, etc.) to the Army for trial. *SAFT is currently working with the Army's RDEC to develop and define LiON® cell sizes and applications for military usage. Even though the Army has not yet come up with a requirements document, SAFT is working on a 20 amp-hr battery that it believe will satisfy the Army's next generation portable radio needs as well as the Air Force's need for a new F-16 battery.*

COMMERCIAL INTENT AND STATUS: SAFT America's commercial objective was to establish a commercial manufacturing line, producing rechargeable lithium ion 18650 cells, at SAFT's military oriented Lithium Battery Division at Valdese, NC. The commercial marketplace, with uses like laptop computers and portable communication, is seeking rechargeable batteries with 100% higher energy than conventional NiCAD® or nickel metal hydride batteries. The LiON® product was expected to answers this need. *Unfortunately, a corporate review determined that their production costs would still be so high that they could not profitably compete with Japanese companies and thus refused to make the multi million dollar commitment that setting up a production line would have required.*

Low Cost Electronic Packaging Through Systems Approach to Ball Grid Array Package Assembly 5046

Ultra Clean International Corporation

BACKGROUND: Ball Grid Array (BGA) packages are expected to become the predominant form factor for high pin-count devices used in both military and commercial applications.

OBJECTIVE AND GENERAL STATUS: This TRP project was let to develop a lower cost and more environmentally friendly approach to assembling BGA packages. The team was to take a systems approach to optimize the materials, processes, and equipment used to assemble BGA packages. Initially, the team conducted research on low cost substrates, reduce the requirement for flux in the reflow process, and complete the development of an ultra low vibration material-handling robot to be installed in a new concept BGA manufacturing cluster. The development of improved processing concepts (plasma clean) in combination with improved handling (low vibration robot) enables higher reliability BGA semiconductor packages that are now used in virtually every electronic system operated by the military as well as commercial applications. *The team developed a 2nd generation BGA packaging tool. Requirements for high levels of flux use as a cleaner as well as a wetting agent were eliminated through the use of an integrated plasma cleansing equipment and a controlled environment reflow process running on equipment developed by the UCIC. This reduces the reliance on environmentally hostile cleaners for removing the flux residue following reflow. A low vibration robot was used to handle substrate trays without disturbing the ball placement as the tray was moved between process steps. This resulted in higher package yields by reducing operator induced defects. However, the up-time of the tool did not meet manufacturing requirements. Mean-time-to-repair was too long.*

MILITARY INTENT AND STATUS: High pin count packages reduce the weight and volume of military computing, communication and navigation systems, especially important in man portable military systems of the future. *Since the 2nd generation BGA tool could not meet manufacturing up-time requirements, it will not be used on military projects.*

COMMERCIAL INTENT AND STATUS: Utilizing the BGA packaging would allow the semiconductor supplier to offer lower cost, higher reliability, high pin count packages required for the new generation of hand held commercial systems. The projected equipment market for BGA assembly cluster in 1997 was $34 million. With the development of this superior BGA assembly technology UCIC expected to capture a significant share of this market. *Two machines were sold, but there is no prospect of further sales of the machine that was developed under the TRP. A 3rd generation machine, that uses different technology to eliminate the problems that became evident in the use of the TRP developed 2nd generation machines, is being built for the commercial market.*

Low-Cost Flip Chip 5163

National Semiconductor

BACKGROUND: Flip-chip assembly is projected to replace wire bonding as the predominant method of connecting to high performance, high pin-count integrated circuits. The consortium assembled to advance flip-chip technology included both suppliers and end-users and was interested in producing a number of military and dual use application demonstrations ranging from desktop printing, through portable wireless communications and Personal Computer Memory Card International Association (PCMCIA) storage cards, to missile guidance electronics and modems for satellite communications.

OBJECTIVE AND GENERAL STATUS: To develop technologies and capabilities necessary for the delivery of low-cost flip-chip assemblies. The consortium was to develop solder bumping capability, test and handling processes and hardware, substrates optimized for flip-chip interconnect, surface mount compatible board assembly processes, and industry standard design rules for area-array and peripheral bumped chips. *Excellent progress has been made by stencil printing followed by electroless nickel plating, instead of costly electroplating, to reduce the present industry cost of $70 per wafer to $36 per wafer. However, single die bonding remains a problem as the wafer bumping process does not directly transfer to die bumping. Solder Jet technology appears to be the strongest contender for success in the single die bumping area. Single die bumping is especially important for military applications where the volume of die required does not justify pumping the whole wafer.*

MILITARY INTENT AND STATUS: The consortium was targeting the fifth major upgrade of the Raytheon (Hughes) built Stinger Missile. As the requirements of the upgrade were an increase of 2.5X in target detection in the presence of higher clutter, there will be an order of magnitude increase in the electronics complexity that must fit in the present Stinger volume and the cost may not increase significantly. The solution to this problem is to eliminate the present hybrid packages and replace them with Multi-Chip-Modules -- Laminate (MCM-L) and utilize the flip chip attachment approach. To overcome the expense of flip chips, it was expected to leverage large volume commercial users enabled by this program. *The flipchip process is still being considered for the upgrade of the Stinger Missile and the process will be installed in a DoD-owned fabrication facility in Maryland for the production of classified parts. However, most military applications require single die bumping because of low volumes and the goal to achieve such bumping at a cost below wire bonding has yet to be achieved.*

COMMERCIAL INTENT AND STATUS: It was expected that if the flip-chip process developed during this project can meet the needs of the consortium users for a low cost, high volume flip-chip substrates manufacturing line, Hewlett Packard, Air Communications, SunDisk, and National Semiconductor would have applications pending. *Commercial applications can presently derive the major benefits from flip-chip assembly because the most progress has been made in the area of whole wafer bumping. National Semiconductor will have a major new product line starting in FY98 that will use the TRP developed technologies. Preamplifiers on flex for disk drives are being sampled (1000 units); projected market is for 4 million units. Flip Chip Technologies, jointly owned by Delco, a partner in this consortium, and K&S, has been put into the business of selling wafer bumping services and has a capability to run 15,000 wafers per month.*

Low Cost, High Density, Sequential Build PWB Manufacturing 5183

Shipley Company

BACKGROUND: The consortium proposed to develop a new Printed Wiring Board (PWB) technology that overcomes the density limitations of traditional PWB fabrication techniques. Instead of building up the PWB from separate laminates that must then be drilled and plated for the between layer interconnects, the Shipley process electroless plates the conductors into channels, lithographically defined in a photosensitive, dry deposited dielectric film. Multiple layers are built up by sequentially repeating this process.

OBJECTIVE AND GENERAL STATUS: The goal of this project is to develop and demonstrate a high volume manufacturing process for high-density Printed Wiring Boards (PWBs) capable of achieving a 50 percent cost reduction relative to current processes for comparable boards. The process was to be compatible with existing PWB manufacturing equipment, enabling small- to medium-sized fabricators to enhance their capability without significant capital investments. The additive process also produces significantly less hazardous waste than competing additive or subtractive metalization processes. The benefits of the technology were to be demonstrated on several military and commercial applications provided by the participants. *New chemistries needed in the PWB process have been demonstrated in the laboratory and will be incorporated into a small volume development line. The initial line has a capacity of about 30 panels per hour. Final testing for electrical parameter drift, temperature stability, survivability under temperature cycling and other reliability tests will be performed on units that come off the small volume development line. Allied Signal, a partner in this consortium, is still targeting a generic analog-to-digital converter board to demonstrate to the military the improvements possible by use of the new PWB technology. The Allied Signal FM&T test board design is a Modular Input VXI (MIX) digitizer board that simultaneously samples and digitizes 8 channels of analog data. This board contains all the A/D, memory and VXI interface functions.*

MILITARY INTENT AND STATUS: High density PWBs reduce the weight and volume of military computing, communication and navigation systems, especially important in man portable military systems of the future. *Military benefits will be derived from the improvements in COTS PWB when the developed technology becomes commercially available.*

COMMERCIAL INTENT AND STATUS: Utilizing high density PWBs will allow the semiconductor supplier to offer lower cost, higher reliability, high electronic modules required in automobiles, computer systems and personal digital assistance (PDAs). *The decision to set up a manufacturing line using this process is still pending on the outcome of final tests. DuPont has already found a market for the dielectric dry film developed under this TRP project. Delco will be testing this PWB technology for engine control electronics to produce an engine/ powertrain controller for GM and other automotive applications.*

Low-Cost, High Performance Tooling By Three Dimensional Printing (3DP™) 3533

United Technologies Corporation

BACKGROUND: A large number of parts are fabricated by injection molding (turbine blades, vehicle parts, etc.). For example, the application of polymer composite parts for new high performance aircraft engines will result in lower weight and increased propulsion efficiency for DoD and commercial aircraft. Unfortunately, forming the dies and molds for these products is time consuming and very costly. Further, dies and molds are often foreign-sourced (principally, Portugal and the Far East). Development of a 3D printing process (3DP™) for making molds will lower the cost of products and enable rapid prototyping. 3DP™ is an additive manufacturing process that creates tooling or components by layered printing. Each layer is created by spreading powder and selectively joining the powder by "ink-jet" printing of a binder material, all under computer control thus allowing the fabrication of a part from a computer generated image. The enabling core technology was funded by ARPA & ONR. MIT is the holder of the patents involved. MIT plans to sell licenses for the 3DP™ technology.

OBJECTIVE AND GENERAL STATUS: The specific objective of this TRP project was focused on the rapid fabrication of tooling for dual use military and commercial applications, and the commercialization of the 3DP™ rapid prototyping process and equipment for use by U.S. Industry. The goal was to achieve a process that reduces the print-to-part time from 2 - 6 months to 1 week. The ultimate goal of the program was to use 3D printing to achieve hard tooling with cooling channels that will produce parts that will not need additional finishing. *The consortium has demonstrated the viability of the 3DP™ process for special tools or mandrels used to manufacture military light weight components by resin transfer molding, and has identified the impact of nonconformal cooling passages (internal cavities) for hydraulic and fluid flow control hardware. Additionally, several sets of unique tooling inserts (molds) that are used for plastic injection molding of automotive, electronic, medical and commercial plastic and metal components have been demonstrated. Some of these have conformal cooling passages which demonstrate their advantage in achieving faster production and higher quality parts by maintaining a more uniform mold temperature.*

MILITARY INTENT AND STATUS: Defense is a large consumer of parts fabricated by injection molding. Even more importantly, this process will lower processing costs for new materials (e.g. ceramics) and drive down the costs of low rate production lines typical of military manufacturing. *Military applications of this capability are under investigation by United Technology and the U.S. Navy. An interesting prospect for the Navy is the reduction of needed inventories by utilizing the 3DP™ machine to fabricate spare parts when needed.*

COMMERCIAL INTENT AND STATUS: The 3DP™ will generate wear-resistant molds rapidly and enable the manufacturing of complex molds that are not feasible today. Thus enabling rapid prototyping, more flexible manufacturing and lower cost in production of injection molded parts. This radically new technology will be effecting a $40 billion a year market. *MIT, the owner of the patent rights for the 3DP process, has sold 5 licensees: Extrude Hone Corporation, for the tooling and production of metal parts, Soligen for castings, Therics for most medical applications, Z Corp. for quick look appearance models and Specific Surfaces for ceramic filters. Extrude Hone Corporation, a small business in the consortium, has developed a commercial unit, the RTS 300. The machine itself sells for $400,000 and two have been sold. The total package, including a license from MIT and instruction to run the complete process, brings the total cost to $1,000,000.*

Low-Cost Packaging Based on Area Bonding Adhesives with X,Y and Z Axis-Conductivity 5069

Merix Corporation

BACKGROUND: The conductive epoxy-based packages offer the advantages of lower cost, solder-free joining.

OBJECTIVE AND GENERAL STATUS: The objective of this TRP program was to develop and qualify several new low-cost packaging approaches that utilize conductive epoxy adhesives and preforms. Applications include direct chip attach, ball grid and pad array packages and simple multi-chip modules. The consortium was to prototype small quantities of several different package styles for electrical and thermal evaluation in cooperation with military and commercial semiconductor manufactures in parallel with the design and construction of a volume manufacturing facility. *This TRP project developed a materials system that can make a reliable*

electrical connection between dissimilar materials, It has better mechanical properties than solder and can be manufactured at lower cost for interconnect patterns that are more complex than 40 connections. However, there is still not commercial product. DARPA's desire to advance leading edge technology from research to production in two years was called unrealistic by the consortium leader.

MILITARY INTENT AND STATUS: High pin count packages reduce the weight and volume of military computing, communication and navigation systems, especially important in man portable military systems of the future. In the latter case, it will be extremely important that the electronic systems also be low cost if they are to achieve wide usage in the field. *While seven military system houses have evaluated the technology, only Northrup-Grumman has shown serious interest in pursuing Loctite, Inc, the exclusive licensee of the technology, to obtain this technology for a military system.*

COMMERCIAL INTENT AND STATUS: Lower cost, higher reliability, high-pin-count packages will be required for the new generation of hand held commercial systems. *Loctite Inc., not a TRP partner, has purchased the exclusive rights to manufacture and sell the adhesives developed by Merix Corp. under this program. Loctite also has set up a large screen printing machine, bought from MPM, to set up a commercial manufacturing line, but no commercial sales have yet occurred.*

Low Cost Packaging Technology for Automotive Electronics 5033

Auburn University

BACKGROUND: This project targets dual-use multi-chip modules (MCM) that combine multiple chips on a common substrate wafer, allowing shared space, power and input-output channels. This contrasts with the less costly, but more space- and power-wasteful, use of discrete (single) chips on a common printed circuit board. MCMs offer higher performance for less weight but remain costly military-only niche items. Meanwhile, today's automotive electronics (especially under-the-hood electronics) are achieving extremely demanding cost, lifetime, environmental abuse, performance and reliability requirements that approach or exceed those of traditional military avionics. Automotive markets now set the pace for the electronics industry while providing production volumes that no aerospace electronics market can approach. Not surprisingly, DoD seeks to merge the performance, cost and durability requirements of under-the-hood electronics with the high performance sought for military avionics while transitioning MCM technology to use in cars. It seeks MCMs qualified for both markets, allowing affordable low-volume defense purchases (vs. very high unit costs for current MCMs). Automotive use of MCMs also meets the rapidly growing electronic content of modern cars.

OBJECTIVE: This design-for-manufacture (DFM) project will develop low-cost high-density laminated substrates, low-cost flip chips and fine-pitch wire bonding for low-cost ball-grid-array MCMs for automotive and avionics uses. The team will develop design and production methods for flip chips, including a photo-imaging production method for "surface laminar circuitry." Other development thrusts include high-density interconnects adequately robust for automotive use; electromagnetic interference (EMI) shielding, test methods and modeling tools; military and commercial product emulators (simulated end items); and MCM testing methods that minimize cost and improve fault coverage. The team will qualify its high-density MCM production methods to automakers' demanding quality standards. The team's three large integrators will develop

MCMs for insertion in their own products. Delco (owned by General Motors) and Chrysler's electronics organization will focus on commercial automotive MCMs; Allied Signal will transition MCMs into air transport and defense applications. Other team members will specialize in processing, materials, reliability testing and software for automated circuit design.

MILITARY INTENT AND STATUS: This project expands a shrunken military-MCM vendor base beset by high unit costs and reluctance by "mil-spec"-qualified vendors to process low-volume orders. This reluctance, plus obsolescence problems for discrete-part MCM assemblies, is already driving MCM users to plastic automotive electronics parts to meet price, warranty and longevity demands and to ensure availability. Such parts offer "six-sigma" quality – vs. the poorer quality representative of low-volume defense parts with high "hand-touch" figures. Other benefits include low-cost addition of board-level functionality in aircraft retrofits; simpler stocking and sparing and globally available replacement; and rapid incorporation of commercial upgrades. Broad automotive MCM use will also generate large statistical sampling fields and operating experience that produce excellent reliability metrics for low-volume production of military MCMs derived from this project.

The team targeted a fuel controller for the T800 gas turbine and low-cost auxiliary power units for fighters. Allied Signal will build these items using product emulators developed by this project for military product design. The company sought lower MCM size, allowing multi-die MCM modules; commercial commonality at the depot-repair level; 50% cost cut; and use of commercial dies. But, the military MCM market will remain small. *The project showed that DFM can cut automotive MCM costs yet meet tough military performance demands Allied Signal is developing common MCM modules for fire-control systems, aircraft fuel controls and an intelligent data acquisition unit that reduces aircraft engine size, weight and cost. However, the company is not implementing any production capacity because very low MCM demand in currently budgeted avionics programs. The company will sideline the MCMs until a military program comes along that could use them. Delco is attaching flip chips and wire-bond devices directly to laminate, which eliminates traditional plastic chip packaging and reducing random noise by 10-100 decibels: a feature of great interest to DoD. GM's Hughes Aircraft division is studying Delco's MCMs for its own defense product lines.*

COMMERCIAL INTENT AND STATUS: While impaired up to now by high costs for discrete-part MCMs, automotive use of MCMs is driven by higher under-hood temperatures and growing electrical power needs. The team targeted a truck anti-lock braking system (ABS). *The project was a success. The team built two prototype MCMs whose low-cost packaging defined critical fabrication and test requirements. One, a high-production-volume Chrysler engine controller, used MCM-L technology to advance EMI testing, EMI-based signal trace routing and substrate design. It greatly reduced EMI emissions over current designs, benefiting military and commercial users. Chrysler will insert it in 1999 and 2000 cars and will produce 6,000,000 MCMs, with more later for radios. Delco committed production capacity to MCMs and GM-Hughes is studying Delco's MCMs for its commercial and military products. Allied Signal built and tested an MCM for heavy-truck ABS. One team member (AMP Circuits) is qualifying its substrate technology with two large users, while another (Avex Electronics, another member, is qualifying its assembly technology from this project and doing pre-production builds. Both have formed built production facilities in place for substrates and assemblies, respectively.*

Low-Cost Plastic Packaging 5062

National Semiconductor Corporation

BACKGROUND: Ninety-eight percent of all integrated circuits (ICs) are currently packaged in plastic, but applications that require high reliability and/or tolerance to wide temperature fluctuations, such as military systems, have had to use costly hermetically sealed metal or ceramic packages for their ICs. Military use of low cost, plastic packaging has been seriously limited due to its low reliability and environmental limitations. Studies indicate that the DoD cannot support a stand-alone military industrial base in the year 2000 and beyond, thus DoD will have to use an installed commercial manufacturing infrastructure to build future military systems. Consequently, it is very important for that infrastructure to be capable of meeting military needs.

OBJECTIVE AND GENERAL STATUS: The objective of this project was to revolutionize plastic packaging technology and create a domestic infrastructure which can provide higher density, higher performance, and higher reliability plastic packages than were available, at lower cost. The goal is to develop the total supply chain from plastic packaging materials supply to a low-cost on-shore assembly source. The new materials and processes developed by the vertically integrated team were to be demonstrated on a number of single-chip and multi-chip modules with dual use applicability. The goals of the program were to achieve a >175C operating temperature, 50% decrease in manufacturing cost, higher thermal dissipation (junction temperature rise < 1C/watt), and elimination of hazardous materials from the packaging process. *The consortium has achieved plastic packaging processes and materials that will meet JEDEC Level-2, no bake, but dry pack, required for shipping, requirements at a minimum. This will result in a savings of 4¢ per package. They have also eliminated "pop corning" due to water uptake, developed a stamping process for fine pitch leadframes, achieved high thermal conductivity for the plastic encapsulant by incorporating AlN powder, and developed an adhesion enhancement coating that is mainly responsible for the attainment of Level 2.*

MILITARY INTENT AND STATUS: With improvements in plastic packaging, an increasing number of high-performance military ICs will be able to shift to plastic for a substantial cost reduction. National intended to develop technology under the TRP so that it could offer for sale ICs using the Mil-I-38535, QML process and meet the SMD criteria. *National Semiconductor has achieved a level of acceptance of its plastic encapsulation technology sufficient to win a contract to install that technology at a DoD owned facility in Maryland for the production of classified parts.*

COMMERCIAL INTENT AND STATUS: New commercial applications, such as automotive electronics, require the same high reliability and severe temperature range operation as has been traditional for military ICs. Lowering the cost of plastic packaging was expected to expand commercial sales into such lucrative markets as the automobile industry. *Migrating plastic ICs from JEDEC level 3, requiring both bake and dry pack for shipping, to Level 2 will produce a 4¢ per package savings for a 160 lead IC. A further saving of 0.15¢ per lead will result from the use of stamped rather than etched fine pitch leadframes. These calculations are based on a 320 pin package. Finally, the inclusion of AlN powder particles in the plastic encapsulant is presently yielding a 2¢ per package saving, (this may eventually be a savings of 10¢ per package) over heat sinks (in the case of high power dissipation ICs). Thus, the lowering of cost for high temperature, plastic ICs is being achieved. Since these industrial/consumer grade plastic ICs are sold through distributors, it is not possible to track the sale of plastic ICs to see which end users they satisfy.*

Low-Power, High-Resolution, Portable Ultrasound Imaging System 12026

Teratech Corporation

BACKGROUND: Existing medical ultrasound equipment is large, heavy and costly; yet, the image quality is well below what is theoretically possible. Medical ultrasound imaging will be significantly advanced by applying charge-domain processing (CDP) integrated circuits (ICs) to reduce the size, power consumption and the cost of the system hardware. By reducing the size and power consumption, each by a factor of ten, ultrasound imaging systems will become portable.

OBJECTIVE AND GENERAL STATUS: This TRP project was to initially develop the technology for achieving a high resolution, portable ultrasound imaging system and then assemble a prototype demonstrator. *A prototype, portable Ultrasound Imager has been assembled and is undergoing extensive evaluation. All the technical goals have been met or exceeded. However, the cost goal of $10,000 per unit now appears to be too optimistic. Present projections have a price of $50,000 for the initial units, dropping to $20,000 in 5 years when the production volume has increased. Even at these prices, the portable instrument is considerably cheaper than the presently utilized hospital ultrasound systems that cost $200,000 and up. The systems in use today are also very heavy, 300 lbs vs. 7 lbs. for the developed system; and consume a lot of power, 400 watts vs. 10 watts. A significant part of the cost increase comes from the fact that the proposed polymer polyvinylidene fluoride (PVDF) transducer arrays did not provide the desired performance and the developed system has to use an expensive PZT transducer array.*

MILITARY INTENT AND STATUS: A portable ultrasound imager can be adapted to the battlefield situation to achieve rapid diagnoses of wounds. Data from a portable ultrasound imager can be used in telemedicine to allow remote specialists to provide diagnostic services directly to paramedics on the battlefield. *One prototype is being presently tested at the USAF Medical Center, San Antonio, TX and 3 additional units will be delivered to Maj. Michael Freckleton, M.D. in Dec. 1998. Six more units are tentatively scheduled for delivery in July 1999, and October 1999, under the proposal for the option year.*

COMMERCIAL INTENT AND STATUS: Reducing the cost of ultrasound imagers greatly broadens the market for ultrasound medical imagers. At the present cost of $100,000 or more for ultrasound imagers, only large hospitals and medical centers can afford the investment. At the projected cost of around $10,000 per system, practicing physicians will be able to afford such systems. This will open up a $2.5-$3 B market in the U.S. alone. It is also believed that at this low price, veterinarians will begin to use ultrasound imaging in their work. *Commercial sales will begin one year after receipt of FDA approval which is presently pending. It is expected that first commercial sales will occur in the 3rd quarter of 1999. However, large quantity sales are now not expected for 5 years when the price can be reduced from the present $50,000 to $20,000 per system.*

Manufacturing Process Development for Thin Multi-Layer (Flat Panel) Antennas 17001

Raytheon Company

BACKGROUND: Most new military procurements for "platforms on the move" call for phased arrays. In particular, phased arrays are called for in the AF UCAV (Unmanned Combat Air Vehicle) program, MILSTAR's airborne terminals, B-2 upgrade, and the Navy's CVX, the new aircraft carrier and MLAS (Multi Link Antenna System). Unfortunately, phased array elements are still too expensive to be affordable by those systems.

OBJECTIVE AND GENERAL STATUS: This project was to develop a design and manufacturing process for small, millimeter wave, flat panel, phased array antennas. The team of developers and end-users were to address the integration and affordability of high performance components for DoD and commercial phased array applications. Its multilevel packaging approach was to reduce phased array antenna element costs by a factor of 10 and create integrated receiver assemblies that improve system performance. The target cost for the array's unit cells was $30-$50 each. Under this TRP, the technology necessary to manufacture low-cost, narrow band, phased array receive modules in the 19Ghz to 40GHz frequency range was demonstrated. The primary challenges that were overcome are: a) minituarization, the need to fit all components into a l/2 periodic cell structure, b) elimination of wires for the control of phase shift functions by modulating an RF carrier transmitted on the corporate feed, and c) design and construction of the phased array antenna elements on three basic layers that are independently fabricated and tested as subassemblies before they are bonded together as a complete phased array antenna. *This approach has brought the initial cost of a phased array antenna element to approximately $100. Projecting a 85% learning curve improvement in cost, one can expect that the target unit cost of $30 per antenna element will be reached after 300 antennas with 2752 antenna elements have been manufactured.*

MILITARY INTENT AND STATUS: Phased array antennas offer significant performance and operational advantages to the military. The immediate military applications for thin, flat panel, arrays include upgrades to airborne Milstar terminals, upgrades to shipboard systems such as NESP, and satellite communication links for systems such as J-STARS. There is also considerable potential to use thin array technology for multi-function apertures, including search and fire-control radars, communications, interrogate friend or foe devices, and electronic counter measures. *A follow-on AF DUAP program for a MILSTAR terminal will demonstrate the military utility.*

COMMERCIAL INTENT AND STATUS: In the commercial realm, the application of low cost, thin, phased array antennas for such uses as direct broadcasting to commercial airliners would help sustain an affordable technology base for the DoD to use if the cost goals are met. *Commercial viability will be tested by working with Teledesic to provide phased array antennas for their satellite up and down links at 28.6GHz to 29.1GHz and 18.8Ghz to 19.3Ghz respectively. When prices come down further via the learning curve, there will be market potential for use in direct broadcast satellite (DSB) receivers on commercial airlines that receive signals from the Global Broadcast System (GBS).*

Microfabrication of Ophthalmic Surgical Knives Process Development and Mechanical Design 2344

Johns Hopkins Hospital

This small project ($130,000 of government funding) to develop better ways to manufacture small, hard, and very stable structures, using IC substrate fabrication technologies, began to have trouble when Storz, the only commercial partner, pulled out before the agreement was signed. The agent, NSF, issued a cost shared grant to pursue the program as a university research project**.** *The liquid chemical etching process did not succeed with sapphire. Gas phased etching was successful, but needs more work. According to the final report this work will continue, but at this time the silicon knives produced were not structurally stable.*

Miniature Filters For Wireless Networks 13003

Northrop Grumman

OBJECTIVE AND GENERAL STATUS: The objective of this project was to provide fabrication procedures, packaging techniques, and rapid computer design tools to reduce the size, weight, and cost of miniature filters. *Although it is too early to judge the success of this project in addressing both the military and the commercial sectors, filter size is about 3 times better than the original goal and tests conducted thus far indicate that bandwidth and loss performance objectives have been nearly met. A major challenge is to produce the filters at a cost sufficiently low to attract commercial sales ($100 per unit for a 1,000 unit buy).*

MILITARY INTENT AND STATUS: The aim was to create a basic capability, with the understanding that specific military application may demand different product characteristics from the dominant (commercial) market. For example, the product may be required to meet military temperature extremes. These application-specific decisions will be made later. These technologies will enable compact filters, filterbanks, and oscillators that will enhance DoD radar, low-cost seekers, smart munitions, ESM receivers, and compact ID location transceivers as well as improve commercial GPS and cellular communications products. Military products from this project will be applicable to JSF, IBAD and, eventually, to radios developed for the Global Mobil projects being sponsored by TRP. *Components using prototypes of this technology have been furnished to a military customer for application to a classified program. Prototypes furnished were acceptable to the program manager.*

COMMERCIAL INTENT AND STATUS: Commercial markets include Global Positioning System (GPS) and cellular communications products. TRFE, a consortium member, is responsible for the commercialization of the end product. The initial market is the GPS and Direct Broadcast System (DBS). *It is too early to expect commercial success.*

Miniaturized Environmental Monitoring Instrumentation Based Upon the Mass Spectrograph Chip 1648

Northrop Grumman (formerly Westinghouse Electric Corporation (WEC))

OBJECTIVE AND GENERAL STATUS: U.S. military services and treaty monitoring and intelligence agencies require easily proliferated portable sensors to detect chemical warfare agents (CWAs) on the battlefield, to non-intrusively detect and characterize contraband materials and treaty-controlled CWAs, and to monitor Department of Energy site cleanups. In particular, U.S. ground forces need CWA sensors that can be affordably deployed at the squad level, rather than costly, bulky sensors whose cost, weight, complexity and support demands restrict them to specialized units operating above squad level.

Meanwhile, major U.S. industries affected by the 1990 Clean Air Act Amendments (CAAA) must monitor themselves for CAAA compliance and to create an accurate record of self-emissions for participating in the "pollution rights" market: a main CAAA enforcement tool. This requires near-real-time sensors that, operating from standoff distances, can continuously and simultaneously monitor multiple pollutants, including chemical precursors of acid rain, smog and ozone; VOCs (volatile organic compounds) and hydrocarbons; and 189 "hazardous air pollutants" (HAPs). Such continuous monitoring poses a major affordability and technical challenges.

This project sought to use microelectromechanical systems (MEMS) technology in a low-cost ion-trap "mass spectrometer (MS) on chip" (MSOC), integrating it with a gas chromatograph (GC) "front end" and a high-performance vacuum pump that could maintain a hard vacuum on the MOSC chip. As MS is the most sensitive "direct detection" method for sensing chemicals, this hardware integration would produce a high-performance, mass-producible, battery-powered handheld or portable sensor of CWAs and CAAA-regulated chemicals. By combining a proprietary MSOC chip with DARPA-funded hardware, Westinghouse planned a 10-pound portable battery-powered unit in Phase 1 with a volume of 3,000 cubic centimeter (cm3) and a sensitivity of 1 part-per-billion (ppb) with 20-minute sample processing. In Phase 2, a 600-cm3 handheld unit weighing six pounds would achieve 1 ppb in five minutes. These goals required a compact, low-power vacuum pump, a low-power MS unit and a low-flow GC column.

MILITARY AND COMMERCIAL INTENT AND STATUS: On the civilian side, the team planned to use chemical separators and pre-concentrators as input stages and to boost the sensitivity of the sensor's ion optics. This would let one cheap sensor monitor multi-gas CAAA pollutants over a size range of 1-650 amu (atomic mass units) to ppb-level sensitivity. This would meet the monitoring needs of major industrial emitters (chemicals, pulp and paper, metal foundries, smelters, refineries), waste remediation sites, semiconductor plants, aerospace plants and two sectors (hospitals and office buildings) where indoor air quality is a liability or regulatory concern. The Phase 2 sensor would target small firms (drycleaners, paint sheds, gas stations, etc.) who cannot afford costly conventional multi-gas analyzers.

However, the team ran into a major technical block: maintaining hard vacuum on MSOC chips with a small low-power pump exceeded the state of the art for the firm's cost, size and weight goals, especially for the Phase 2 handheld sensor. This led to an 18-month slip and use of a bulky, costly conventional pump; the firm has a separate DARPA award for a micro vacuum pump. The team has chosen to forego a Phase 2 device. The MSOC chip demonstrated one-year continuous operation and a 10-fold sensitivity gain. The prototype Phase 1 integrated sensor is a 24x15x9 inch, 35-lb, $50,000 device whose high-speed microcapillary GC column and micromachined injection valves allow 2-minute elution times (vs. 20 minutes for current GC/MS units). The sensor meets Army requirements for man-portable squad-level CWA sensing and approaches Navy shipboard requirements, but no military transition is planned.

Commercially, the team sees no one-for-one replacement of current lab instruments, but is targeting markets needing cheap high-performance chemical sensors. While unit costs currently are too high for the small-business market seen in market studies, Westinghouse's new owner (Northrop Grumman) is encouraged by queries on licensing and teaming.

Model Based Control and Diagnostics (MBCD) 10018

General Electric

BACKGROUND: Boosting the performance and lifetime of gas turbines, automobile engines and other powered mechanical systems requires engine controllers that can detect, isolate and eliminate problems that can cause major breakdowns. This task requires sensors and intelligent software algorithms that can closely track the engine's operating state and fine-tune its desired performance. Likewise, internal-combustion engines used in cars and trucks must meet rigid air-pollution limits that extend beyond 100,000-mile engine life. This requires real-time sensors, diagnostic algorithms and feedback controls to adaptively track the engine's operating state. This project sought to capitalize on both needs.

OBJECTIVE: The team will develop MBCD software for controlling gas turbines and internal-combustion engines. MBCD embeds a uniquely adaptive nonlinear real-time model in the engine's digital controller, improving engine thrust-to-weight ratio, fuel consumption, reliability, weight and cost. The controller's diagnostic intelligence lets the engine run efficiently with fewer diagnostic sensors. In addition to boosting engine performance, the payoffs include lower maintenance and operating costs and more cost-effective validation of changes in engine control laws.

MILITARY INTENT AND STATUS: Candidates for MBCD include F100, F110, F118 and F414 engines on F-15E, F-16C/D and F-18E/F fighters, Joint Strike Fighter (JSF) engines and aeroderivative marine gas turbines like GE's LM-2500+, LM-5000 and LM-6000. The project has moved smoothly, with good DoD transition prospects. Service tests found MBCD's accuracy unprecedented, giving aircraft onboard diagnostic processing capability now available only on the ground. *The JSF program is weighing MBCD for engine diagnostics, although JSF's cost targets have not been met and it is too early to tell if MBCD will meet JSF requirements for weight, size and performance. It also is funding an MBCD-based "intelligent maintenance advisor for turbine engines" (IMATE). The team tested condition-based maintenance (CBM) methods that eliminate certain sensors and developed simplified control laws for a non-flight JSF engine. The Office of Naval Research (ONR) will use MBCD in several CBM projects. The Marine Corps is assessing MBCD for the diesel engines of its Advanced Amphibious Assault Vehicle (AAAV).*

COMMERCIAL INTENT AND STATUS: The team is targeting U.S. airlines and Ford Motor Co.'s products. Ford will fold its neural-net analysis (NNA) methods for engine-misfire detection into MBCD. This yields simple, accurate, low-false-alarm-rate diagnostics for CBM, which must meet very stringent requirements at acceptable false-alarm rates. Ford studied DoD control and diagnostic needs for current and future platforms and benchmarked MBCD's size, complexity and other factors against non-MBCD designs. *Ford's project work in automotive NNA networks includes a "virtual sensor" that could greatly reduce the complexity and cost of CBM monitoring. Ford will transition MBCD hardware to its car lines within several model years. In another commercialization thrust, Lockheed-Martin will apply MBCD to aircraft flight controls.*

National Academic Medical Center Information Collaborative 2765

SAIC (took over from Bell Atlantic)

OBJECTIVE AND GENERAL STATUS: The U.S. faces a major problem in boosting medical research productivity: the non-standardization of medical definitions in large research databases at leading academic medical centers (AMCs) makes it difficult to develop a unified view of data for those medical studies (e.g., outcomes studies, preparations for clinical trials of drugs or devices) that require large data fields. Because of non-accessible databases, such studies tend to understate the real population of interest. This data-field deficiency affects civilian care and military care offered by military hospitals and R&D centers like the National Naval Medical Center (NNMC). The impossibility of rebuilding AMC databases around shared definitions and search identifiers prompted interest in software "brokers" that convert existing AMC databases into a single "virtual database" without changing the AMC database structure. In doing so, the team also sought to protect patient confidentiality.

MILITARY AND COMMERCIAL INTENT AND STATUS: *This eight-AMC project began as an effort by its leader, Bell Atlantic, to expand the market for its OASIS medical-database software to regional and metropolitan medical databases. When Bell left this software market, DARPA asked SAIC to run the project. SAIC brought in NNMC and refocused the project on cross-database "brokering" with breast cancer as the target. By its end, the project had achieved most of its TRP goals, with the rest achieved later. It demonstrated an Internet-accessible virtual breast-cancer database that can use legacy databases built with varied information technologies, models and data structures. The team set up inter-AMC links (extended to the National Cancer Institute in Bethesda, Md.) for collecting digitized mammograms, with NNMC archiving them. Images were sent to Georgetown University (GU) over ATM (asynchronous transfer mode) links for analysis by GU's interpretive algorithms. SAIC worked with Lockheed Martin Corp., now developing a DoD image repository, to adopt its new DICOM 3 interface for digital-image archiving. Successful spinoffs include DICOM-3, now used at several DoD facilities, which may be commercialized in General Electric's medical imaging and image management products; process-flow software, which will be extended to NCI with DARPA support; and Columbia University's informatics and lexical standards for standardizing doctors' verbal descriptions.*

National Industrial Information Infrastructure Protocols (NIIIP) 2550

NIIIP Consortium

BACKGROUND: Interoperability of business interactions is required amongst DoD suppliers with different skill sets and organizations having different information processing environment, business processes, and business practices. This project will enable geographically separated organizations to electronically link into "Virtual Enterprises" to access, share, and communicate manufacturing design solutions. A Virtual Enterprise is a temporary consortium of independent member companies which come together to form a team to provide products/solutions that quickly exploit fast-changing product design, development and manufacturing requirements (The DoD supplier Supply Chains are good examples of Virtual Enterprises). Virtual Enterprise companies share cost, skills, and core competencies that collectively enable them to develop solutions that could not be provided individually.

OBJECTIVE AND GENERAL STATUS: The goal of the National Industrial Information Infrastructure Protocols (NIIIP) Project was to develop open industry software protocols that will

make it possible for DoD suppliers and their manufacturers to effectively interoperate as if they were part of the same enterprise. The extended object model was used as a build-time tool to model heterogeneous resources. The resulting meta information is used to automatically generate program stubs and skeletons for achieving the interoperability of heterogeneous systems over OMG's ORB. *The concept and technique of "rule-based interoperability" among heterogeneous application systems was demonstrated in this project. The developed technology is an object-oriented knowledge base management technology, which allows all things of interest to be modeled as "active objects." Operations performed on these objects can be considered as events, which trigger the processing of knowledge rules. These rules can represent data constraints, integrity and security rules, military regulations and policies, battlefield conditions, etc. The developed technology can be the basis for implementing intelligent systems for military and defense applications.*

MILITARY INTENT AND STATUS: The increased efficiency of the U.S. manufacturing base which will result from the success of this project will enable tremendous cost savings for military procurements, both in terms of defense-specific manufacturing as well as in terms of the price of commercial products of use to the military. *The software technologies developed by the TRP consortium are already forming the basis for software being used on DoD programs by General Dynamics, Electric Boat Corp. and Lockheed Martin. Electric Boat Corp. considers a potential saving of $20.5M per ship attributable to the NIIP-based software projects. Similarly, Lockheed Martin estimates potential F-22 cost savings of $700K / unit and JSF Life Cycle Cost savings of $3B that are directly attributable to the NIIIP TRP effort.*

COMMERCIAL INTENT AND STATUS: NIIIP will consolidate, rationalize, and integrate a set of standard upon which applications will be built and virtual enterprises will be formed. *Five companies have developed over 30 specific SW programs that have their bases in NIIIP developed technologies.*

Next Generation High Resolution & Color TFEL Displays 5040

Planar

OBJECTIVE AND GENERAL STATUS: Assuring the commercial availability of affordable, high-performance flat-panel displays (FPDs) has concerned DoD for over a decade. The growing information intensiveness of combat makes the display a central factor in the combat performance of soldiers and airmen. Such displays face unique requirements for broad temperature range, sunlight readability, shock resistance, maintainability in harsh environments, and power draw. DARPA's High Definition Systems (HDS) program funds leading-edge R&D in helmet-mounted displays (HMDs) and larger displays, from desktop/laptop size to command-post size (e.g., 120-inch diagonal) FPDs. DARPA seeks major improvements in life-cycle cost (LCC), mean time between failure (MTBF), weight, ruggedness and power efficiency. Yet DoD cannot afford the high unit prices of small production runs of military-unique FPDs. Meanwhile, most major U.S. computer integrators buy their FPDs, especially the benchmark AMLCD (active-matrix liquid crystal display) FPDs, from Asian vendors. This dependency has led DoD toward dual use FPD options and next-generation FPDs that match or outperform AMLCDs but are domestically producible.

MILITARY AND COMMERCIAL INTENT AND STATUS: DoD is especially interested in non-AMLCD FPDs like TFEL and AMEL (thin-film and active-matrix electroluminescent) and

FED (field-emission displays) designs. DoD now uses more EL displays than any other type. Their ruggedness, wide viewing angle and wide temperature range also make them suitable for HMD use. AMEL combines TFEL technology with integrated-circuit semiconductor technology to eliminate the need to separately attach "display driver" chips to the display. This allows a fast, high-pixel-density display with extreme ruggedness, low power consumption, high brightness and contrast, and low weight. TFEL/AMEL-based HMDs can be worn by airmen, tank and truck drivers, dismounted soldiers and medics. Military uses of non-HMD mini-FPDs include personal viewers like wearable displays and GPS navigation units, as well as see-through sights like targeting and weapon sights, night-vision goggles (NVGs) and heads-up displays (HUDs), and rangefinders. Parallel commercial markets are varied. HMDs can be used in field-maintenance borescopes, process control and warehousing aids, 3D image analysis, minimally invasive surgery (e.g., endoscopy), video and game gear, portable computing and 3D content analysis. TFEL/AMEL personal viewers can go into barcode readers, wireless fax, e-mail and cell phone appliances, digital cameras, patient data displays and navigation, while TFEL/AMEL see-through sights are useful in surveying and construction-site visualization, augmented assembly, microscopic display, image-guided surgery and navigation.

This project targeted emerging DoD demands by developing manufacturable AMEL mini-displays and HMDs, a high-resolution direct-view black-and-white TFEL display for a new FLIR (forward-looking infrared) sensor on the M-1 tank and a small color TFEL unit for armored vehicles. These can tap the production economies of the project's industrial and consumer FPDs. The project was a success, meeting all TRP milestones and technical criteria for its AMEL and TFEL displays. One test unit achieved over 70 times the operating lifetime of the military CRT it will replace. Early production yields exceeded 60% and the first commercial AMEL displays have been well received. The Army's Land Warrior program will buy 15,000 AMEL HMDs from the project, with other buys for a mine detection system, laser rangefinders, a British fire-support and target acquisition system, and Air Force NVGs and HUDs. The TFEL FLIR and mini-display for tanks were demonstrated to military users and exceeded their requirements. The latter unit is also scheduled for the Air Force's F-16 fighter.

Object Technology for Rapid Software Development and Delivery 5165

Anderson Consulting

OBJECTIVE AND GENERAL STATUS: Modern software systems are among the most complex human-made structures ever built. The high software dependence of defense functions like battlefield communications, electronic warfare, data fusion and real-time situation assessment, as well as the services' need for robust, distributed software networks for chaotic environments and mobile users, requires advances in software generation and reusability to cut development cost and time and improve the ability to evolve software. Similar problems bedevil non-defense software users. An August, 1998 Presidential Information Technology Advisory Committee report noted that both sectors depend on fragile, unreliable software whose development, testing and evolution are labor-intensive and difficult. Escalating software demand, led by growth in computer performance, Internet connectivity and software-intensive communications, sensing and control networks, far exceeds U.S. software production. Tools for constructing and analyzing software are inadequate. The growing complexity of systems, growing shortages of software programmers, nonstandardization and poor upgradability create a "software crisis."

One solution is to construct libraries of certifiably robust, reusable software "building block" modules. Today's software developers must manually integrate tools and applications. Often they cannot reuse such software on later projects, due to lack of standards, or must recode functional prototypes written in older languages into portable, more widely used languages like C++. Current CASE (computer-aided software engineering) tools allow only limited prototyping, do not support system evolution and do not allow user perspectives on evolving systems. DARPA's USE (User-centered Software Engineering) and EDCS (Evolutionary Design of Complex Software) projects have tackled these issues in the ROAD (Rapid Object Application Development) consortium.

MILITARY AND COMMERCIAL INTENT AND STATUS: This TRP-funded ROAD project sought a new model in software engineering that lets analysts and developers virtually team in software development over time to assemble customer-specific software from reusable, extensible modules ("objects") that meet emerging object-management standards. Its innovations (module reusability and specification of new components through high-level languages and integrated graphical interfaces) were to be tested in a commercial product (a factory work-center planner from Raytheon) and a defense application, Raytheon's Capabilities-based Battle Management System (CBMS). The latter is a planning system for time-critical iterative analysis that gives an operations officer a three-dimensional view of combined weapon system capabilities and lets him optimize his force deployments. Battlefield management demands the flexibility, rapid growth and modularity that are central features of object-based software techniques. Because the iterative nature of object-oriented software development does not fit with traditional DoD contracts, built around fixed delivery schedules and delivered functionality, leading to delivery times up to seven years long, ROAD would also pioneer new software contracting methods.

The project met its technical goals, with the Air Force project manager calling it "outstanding." Its technology is transitioning to defense and commercial use through internal product development at Raytheon, which is using ROAD advances on defense proposals and five product lines, and at Anderson Consulting, aiding Raytheon on both applications. This cross-product/sector approach makes Raytheon a leader in software systems integration. DoD's Software Engineering Institute (SEI) scores Raytheon's software engineering processes highly in "Capability Maturity Modeling" (CMM), a crucial metric in contractor selection. ROAD advances are also useful for DARPA's "Command Post of the Future," the Navy's DD-21 future destroyer and the Army's Medium Range Extended air Defense (MEADS) missile. In commercial markets, ROAD can also be used in telemedicine, information management and network management.

Pad Printer 5011

MultiLythics

BACKGROUND: The pad printing technology, adapted from long use in the production of fine dinnerware, will be applied to the of deposition of finer conductive lines and smaller passive components than current silk-screen printing approaches permit. The potential value of this development to the military and civilian electronic industry is large. This industry is estimated at $4+ billions in annual sales, a domestic employment in excess of 30,000, and has been growing at around 6% per year. Like semiconductors and printed circuit boards, the costs of hybrid circuits are roughly constant in $/cm2 of manufacturing "surface." This technology offers over 5x the wiring density of conventional thick film hybrid and MCM-C circuits manufactured by silk screening at essentially identical cost per unit area.

OBJECTIVE AND GENERAL STATUS: To develop a dramatically improved printing technology for the production of thick-film hybrids and multi-layer ceramic packages. *A prototype machine that can demonstrate the achievement of the technical goals was realized. The program continues under customer co-funding to develop a production viable tool for pad printing of hybrid circuit layers.*

MILITARY INTENT AND STATUS: This TRP effort will allow thick-film hybrids and ceramic multi-chip modules (MCMs), which are widely used in military applications, to be significantly reduced in size and produced at lower cost. Size reduction is particularly important for military applications as increased capability is continually being designed into weapon systems. *No products that use this technology are yet available for military insertions.*

COMMERCIAL INTENT AND STATUS: Since the circuit made by the pad printer technology can be much smaller, dramatic reductions in device cost are possible. Simultaneously, the new technology permits the same or higher circuit performance, leading to faster growth for this semiconductor industry segment. *A spin-off from this development is the sale of inks, originally developed for the precision pad printer, to other less capable, commercially available pad printers generally used in the porcelain industry. Active negotiations are underway with three customers - one foreign - for commercial sales of the precision pad printer (potential sales is 30 printers).*

Passive Millimeter Wave Camera 1167

TRW Space and Electronics Group

BACKGROUND: Aircraft operation in low visibility has long challenged military and commercial aircrews. Advances in low-cost fabrication and packaging of millimeter-wave monolithic integrated circuits (MMICs) have renewed interest in passive millimeter-wave (PMMW) radiometric imagers, up to now limited by high costs and immature technology. PMMW sensors embedded in cockpit synthetic or enhanced-vision systems (SVS, EVS) emit no RF (radio frequency) signals, allowing covert special-operations flight, while their frame rate, image latency and resolution allows low-visibility landings and takeoffs. Their high-resolution, low-clutter TV-like image requires minimal processing. They outperform FLIR (forward-looking infrared) sensors, which are hampered by smoke, clouds and day/night temperature changes, and imaging radars, which suffer high ground clutter, false horizons and poor minimum range. They can penetrate fog, rain, blowing sand and dust.

OBJECTIVE: The team is developing and flight-testing a PMMW camera and developing low-cost production methods. The imager uses a direct-detection W-band millimeter-wave radiometer receiver, mounted on an integrated-circuit chip, that operates at 90-GHz (gigahertz) wavelength at 20 frames/second.

MILITARY INTENT AND STATUS: With PMMW, airlifters can fly into forward theaters without prior deployment of ground-control approach (GCA) radars, allowing more responsive airlift. Other roles cover special operations, search and rescue (SAR), coastal surveillance, drug interdiction, ship navigation in fog, driver vision, counter-terrorism, land-mine detection, air defense, standoff weapon delivery, and battlefield targeting and surveillance. In the last two roles, PMMW can see through battlefield obscurants, including spectrally tailored smokes designed to defeat infrared- or radar-guided weapons. The project has been a technical success and TRW is optimistic about the camera's prospects. *NASA-funded flight tests in 1997 aboard the Air Force's*

C-135 "Speckled Trout" sensor testbed demonstrated PMMW's use for bad-weather landing and takeoff operation. The Air Force-run Joint Program Office for the Autonomous Landing System and Boeing have sought price quotes for a production camera. NASA is another strong advocate. The Office of Naval Research (ONR) and the Marines are testing PMMW for special-operations patrol craft, with ONR also funding helicopter SAR tests for the services and the Coast Guard.

COMMERCIAL INTENT AND STATUS: TRW sees its best U.S. market in weather-sensitive just-in-time air-cargo operations. Adding PMMW to cockpit SVS/EVS systems allows low-visibility operation at 1200+ airfields (vs. 38 today) and reduces the radar hardware that airports now buy for low-visibility landings with current radars. It is the only sensor that lets a pilot independently land, turn off, taxi and park in low visibility. Airport controllers can also guide aircraft on the ground in bad weather. *TRW reports many requests for airborne oil-spill detectors and cameras for harbor patrol and coastal surveillance. It is quoting prices and delivery dates of 12 months or less.*

Portable 3D Imaging Ultrasound Systems Based on 1.5-D and 1-D Integrated Arrays 12013

Guided Therapy Systems (GTS) / Albatross Technology

BACKGROUND: This project was proposed to develop technology needed for the first portable, compact, three dimensional (3D) medical imaging ultrasound system. Today, most ultrasound images are two dimensional slices; this device was to provide a new dimension in ultrasound diagnostics. A compact, real time, 3D imaging system represent a totally new product that will not only serve existing clinical needs, but will open new diagnostic and monitoring applications in combat casualty care, civilian emergency response, and general radiology. This dual use development was to ensure that this exciting new capability would also meet the unique medical needs of the military on or near the front lines.

OBJECTIVE AND GENERAL STATUS: The system to be developed was to feature mechanically-scanned 1.5 D ultrasonic arrays (arrays fully populated in one dimension, but with only a limited number of rows in the other dimension) to form ultrasound images of a 3D volume of tissue. Additional features of this project included beamforming electronics integrated with the transducer arrays, unique interconnection technology, and a modular approach to imaging software for ease of data transmission. *A prototype instrument performed in accordance with specifications and the needs of the military medical tasks for which the instrument was designed.*

MILITARY INTENT AND STATUS: The 3D ultrasound imaging system has applications in combat casualty care to facilitate the assessment of internal organ damage, locate fractures and foreign objects, monitoring the healing of wounds and lesions below the skin surface, identify disease and other pathologic conditions and for general radiology. The first phase of this program was to develop a prototype and the second phase was to commercialize the system. *Since only the first phase of the TRP was funded, no instrument for commercial or military use has resulted.*

COMMERCIAL INTENT AND STATUS: Civilian emergency and disaster response personnel have needs for the 3D ultrasound imager for applications similar to those found in military casualty care. *Even though the TRP was terminated before the commercialization phase of the program was to begin, the project did result in components that have found their way into the commercial marketplace. The computer host is available through Digital Equipment Corporation in*

configurations from $2500 to $30,000, 3 dimensional probes will soon be available for $15,000 each, a phase aberration correction package has been licensed for $200K, and the communication package is a commercial product. The details on the numbers that have been sold are considered proprietary.

Portable Shipbuilding Robotics

Cybo Robots, Inc.

BACKGROUND: A weak commercial U.S. shipbuilding industry poses a clear threat to national security and deprives the U.S. economy from the benefits of participating in a $36B market. The development and implementation of flexible robotics will help shipbuilders improve military construction competitiveness as well as potentially enable some of the productivity gains required to compete in the world commercial market. Members of this team are CYBO Robotics; Trellis Software & Controls, Inc; K2T, Inc; ARM Automation, Inc; Stanford University; University of Texas at Austin; Edison Welding Institute; Ingalls Shipbuilding, Inc.; National Steel and Shipbuilding Company (NASSCO); Bath Iron Works; Naval Surface Warfare Center-Carderock; and NIST.

OBJECTIVE AND GENERAL STATUS: To create a total robotic welding system suitable for the cost-effective construction of any kind of ship, in any quantity, focusing primarily on lightweight arms that can be disassembled for insertion into the workspace and better low cost sensor technology. This system provides manufacturing technology to reduce ship construction costs, improve ship quality, reduce design weight, and improve the safety of the manufacturing environment. In welding and cutting applications, this technology has shown a 16 to 1 reduction in manufacturing labor. Activity goals include a total flexible robot system that will enable 50% to 75% of a ship to be robotically welded; 25% to 50% savings on welding costs; improved quality, leading to a 50% to 80% reduction in inspection and rework; and lower cost robots. *The project started in September 1994 with the goal of providing a total, fully integrated system, performing demonstration welds on actual shipyard components by June of 1996. The team did not anticipate the impact of Y2K, the back down of its university partners and early commercialization of the Cutting and Marking Application, all of which have hampered development. The individual technology pieces were prototyped and tested by 1996, and Cybo was demonstrating the prototypes performing straight line welds by February 1996. In November 1997, an integrated system demonstration showed the ability of the technology. A successful project demonstration was held on March 23, 1998.*

MILITARY INTENT AND STATUS: *Cybo notes that transition to the Navy was successful. Cybo has spent $350K of its own funds to support field trials of the demonstration system in a Navy production shipyard. Approximately 299 Navy Sea-Lift ship details and three panel assemblies have been tested and demonstrated to date. The tests have been successful and the technology is functioning as planned. The demonstration system is being readied for six-month field trial at NASSCO shipyard.* Cybo is seeking sources of federal funding to support long term demonstrations of technology in military shipyards to educate potential users and resolve compatibility issues. Additionally, further military funding is need for the development of application specific software to apply the technology to additional functions and for demonstration to military contractors to resolve incorporation issues. The market surveys have shown that there are significant opportunities to apply the technology in other military applications such as aircraft

inspection, aircraft paint stripping, armored vehicle manufacture, rocket engine manufacture, field construction, weapons handling, weapons decommissioning, etc.

COMMERCIAL INTENT AND STATUS: *This activity also provides a means for the U.S. robotics industry to develop a large and much-needed market. Commercialization of the technology for adaptive robotic Cutting and Marking is complete. Cybo has spent more than $4M of its own funds to date to commercialize the technology and will continue to do so in the future, seeking investors. To date, $2M in delivered shipyard orders and $1.2M in commercial orders has been accomplished, including three structural steel cutting systems that have been shipped and are running production at Alabama Shipyard, Avondale Shipyard and Caterpillar. Portable robot welding technology will be ready for commercialization in eight months. Over $10M in additional sales and investments in product commercialization are planned over the next three years. NASSCO shipyard had made modifications to their existing panel line gantry. The modifications are necessary to support the six-month field trial of the TRP semi-portable track based robotic welding system. NASSCO had forwarded manufacturing drawings to Cybo so that they may begin preparing weld files for their upcoming production. The system is slated to initially weld one of the typical five transverse frames per panel.*

Portable Ultrasound Device for Battlefield Trauma 12014

University of Washington, Seattle

BACKGROUND: While most wounded soldiers transported to field hospitals survive, a large percentage of wounded bleed to death before they can be transported. Front-line combat medics can reduce these casualties by using diagnostic ultrasound imagers to detect metal fragments (bullets, shrapnel). Such imagery can guide minimally invasive surgery (MIS), which requires accurate location of wounds, pooled blood and shrapnel. Used externally, ultrasound imagers display organs and tissues in thin "slices" at 10 times the resolution of magnetic resonance imaging (MRI) and computerized tomography (CT), which demand more elaborate facilities and technology. Imagers can also incorporate telemetry for transmitting ultrasound scans to out-of-area radiologists for prompt diagnosis.

OBJECTIVE: The project team used advances in application-specific integrated circuit (ASIC) design to build and field-test a rugged hand-held imager, with Advanced Technology Laboratories (ATL) integrating and producing the device. The team planned to design and produce ASICs for transmit/receive beamforming, digital signal processing, and image generation; to assess the imager's use for mapping shrapnel, internal bleeding and blunt-trauma effects and in guiding MIS therapy; to develop specifications for military and civilian imager variants while maximizing manufacturing and component commonality; and to test tele-radiology links with the imager.

MILITARY INTENT AND STATUS: Front-line MIS lets the Army stabilize patients at the front and evacuate them by truck rather than air-evacuating them immediately after stabilizing them. Such care requires rugged, portable and affordable ultrasound scanners, unlike today's 350-400 pound, refrigerator-size ultrasound imagers costing $250,000-$500,000. Ultrasound imagers can be mounted on probes for direct insertion into wounds or can be used externally. Unlike MRI and CT, ultrasound can image pooled and circulating blood, which is crucial for assessing combat wounds or civilian gunshot wounds and accidental trauma. *The team has built a 5-lb DARPA prototype and is seeking a March, 1999 funding option for color-flow Doppler detection of blood-flow volume, direction and pooling. ATL is promoting the scanner for DoD's telemedicine ACTD*

COMMERCIAL INTENT AND STATUS: The project is meeting its goals and schedule. The team has built a 2-lb commercial variant, has tested revolutionary ASIC ultrasound transducer cells with a dynamic range of eight orders of magnitude, and has achieved image compression of 500:1. *Although its market research finds the DARPA device not suited for commercial markets, ATL sees a $200-$500 million commercial market by 2004 and has set up a spinoff firm (Sonosight) to target two initial markets: ob-gyn (obstetrics and gynecology) and cardiology*. Civilian markets also include ambulance crews.

PowerPak 2678

Martin Marietta Armament Systems (MMAS)

OBJECTIVE AND GENERAL STATUS: This project sought to combine a Wankel-cycle rotary engine from the Hunter unmanned air vehicle (UAV) program with a powerful, compact permanent-magnet generator to create a high-performance, multi-fuel mobile generator set (gen-set) that is two-thirds smaller and lighter than current gen-sets. Whereas current military gen-sets tend to be single-fuel systems powered either by bulky, heavy diesels or by costly, fuel-inefficient gas turbines, PowerPak could burn heavy logistic fuels like diesel to power a growing array of high-powered mobile and transportable air- and missile-defense radars, command and communication sites, hospitals and other sites.

PowerPak's military and commercial version were to have high commonality. Its power electronics allowed constant-frequency output at variable generator speeds; its generator could be driven by power sources like gas turbines or clean-burning diesels, allow its use in auxiliary power units (APUs) aboard tanks, ships and other military vehicles. Targeted commercial markets included construction projects, emergency generators for utility-network breakdowns or outages, customer-site UPS (uninterruptible power supplies) for industrial processes that cannot tolerate network power outages, and "distributed generation" network architectures for electric utilities.

MILITARY INTENT AND STATUS: *The project was premised on full DoD funding, and successful industry development, of an immature rotary engine and on sustained contractor commitment. However, the project failed when none of these conditions were met. DoD cancelled the U.S./Israel Hunter project, leaving PowerPak without a technically mature prime mover. Cost overruns by contractors for the engine and the motor/generator led to bailouts of these vendors by the prime contractor. The division performing the PowerPak contract saw four changes in ownership over the project's history, with the project's "fit" with corporate product lines in continuous flux over its lifetime.*

COMMERCIAL INTENT AND STATUS: *Despite PowerPak's demise, other gen-set options emerged through TRP: e.g., an Allied-Signal turboalternator that is now being marketed to commercial "micro-generation" and "distributed generation" electric-power markets. Prototype PowerPak hardware remains available, including a nearly complete permanent magnet generator.*

Precision Laser Machining (PLM) 1493

TRW

BACKGROUND: Laser machining is currently inhibited by insufficient power density at the work piece, inadequate average power that limits the processing speed, high maintenance requirements, and non optimal beam delivery systems. Recent DARPA-funded developments in diode pumped solid state lasers and technologies to produce high brightness beams (to enhance focusability) makes it possible to overcome these processing limitations. The U.S. laser manufacturing and technology base will be revitalized by developing and applying a new generation of flexible laser machine tools. These tools will provide critical performance improvements for a high leverage manufacturing processes to machine and join advanced high strength metals and composite materials at precise tolerances and at a cost lower than conventional methods.

OBJECTIVE AND GENERAL STATUS: The purpose of this project was to develop precision laser machine (PLM) tools for drilling, cutting, welding, and heat-treating a variety of mechanical and composite parts on manufacturing assembly lines. *Process tests with subscale lasers have yielded previously unachievable results in the drilling of high precision fuel injection holes for diesel engines used in military vehicles and heavy equipment (the smaller diameter holes with reduced taper decrease damage to the parent material) and the successful drilling and cutting of very hard materials such as galvanized, painted titanium sheet, high nickel steel alloys and high carbon steel. Unprecedented laser cutting of graphite epoxy composites, used in airframes like the Comanche helicopter and the Osprey, have been cut with finished "polished edge" quality without the normally observed charring and delamination.*

MILITARY INTENT AND STATUS: PLM will enhance the production of the most advanced and affordable next generation military systems. Through the implementation of more precise laser beams, with variable pulse formats, manufacturers of aircraft engines will be able to drill holes with increased precision and reproducibility. The net benefits, to platforms like the F-119 engine on the F-22 Advanced Tactical Fighter, are more efficient cooling, doubling of component life, and reduced life cycle cost of $100M per engine fleet. Improvements in the cooling channels for commercial and military aircraft engines are expected to lead to 3% increase in fuel efficiency or the ability to run engines cooler and greatly increase component life. Applying this process to aircraft wings to remove turbulent boundary layer and reduce drag can result in additional aircraft fuel efficiency improvements of more than 5%. Laser cutting of composites applied to advanced low observable airframes, and to platforms like the Comanche helicopter and the V-22 Osprey will result in more than $10M manufacturing savings per airframe and the elimination of environmentally unsound cutting with abrasive water jets. Expanded use of composites will also provide significant fuel savings. The new lasers will also promote implementation of a number of environmentally-compliant processes for ship maintenance including laser cladding for chrome plate replacement and laser cleaning of surfaces contaminated with hazardous materials. *Laser cutting of graphite epoxy composites, used in airframes like the Comanche helicopter and the Osprey, was demonstrated with unprecedented "polished edge" finished quality without the normally observed charring and delamination.* In addition, high powered lasers, that can use components that were developed as part of this TRP program, will find utilization in military programs such as Active Tracker Laser, Airborne Laser (ABL), Space Based Laser, next generation THEL for theater missile defense, IR/EO countermeasures, Mobile Ordinance Destruction System, and active remote sensing for chemical/biological warfare agents.

COMMERCIAL INTENT AND STATUS: TRW is in the business of selling high powered lasers PLM applications. The primary initial application will be in the automotive industry where reduction in auto manufacturing costs of $185 per car through pervasive use of laser welding is possible. Industry experts project that this translates to an increase in market share and increased annual sales revenues of $1.7B. Direct laser machining of galvanized and painted sheet metal minimizes machining steps for automotive and airframe manufacturing. *The TRW commercialized DP-11 Precision Laser Machine, with guaranteed 500W average power, is being incorporated by SPARTA into a system for the destruction of unexploded ordinance and by Cummins Engine Company for use in evaluating its potential in drilling and machining applications.*

Pyrotechnic Actuated Vehicle Rescue Equipment 1197

Hi-Shear Technology Corporation

OBJECTIVE: The commercial goal of this project was to reduce logistical demands of supplying electrical power on site required by electrically operated rescue equipment, and the weight and cost of using hydraulic power for this equipment, by substituting pyrotechnic devices. The military goal was to provide stability for an industrial base which is principally military and shrinking due to reduced military buys of pyrotechnics.

MILITARY INTENT AND STATUS: It is hoped that this activity will preserve defense pyrotechnic production capability and add explosive driven cutters, spreaders, and rocket engine Igniter technologies to the defense base. Further, this new generation of rescue equipment will be portable, and therefore more capable of being used in military search and rescue helicopters.

The Army Research Laboratory (ARL) and the Army Research, Development and Engineering Command (ARDEC) awarded several procurement contracts to Hi-Shear to build a Laser Ignition System (LIS) for large caliber guns (155 mm howitzers), in which the laser beam is transmitted to the propelling charge in the cannon through an optical fiber, causing ignition. Because the work was extremely successful, PM-Crusader selected the LIS as the main igniter for the 155 mm howitzer (called the XM297 Advanced Solid Propellant Armament System (ASPA)). ARL entered into a CRDA with Hi-Shear to help make improvements to the LifeShear cutters. Subsequently, ARL awarded a Phase I SBIR to Hi-Shear to design a small portable laser which could be used both to ignite the cannons and the LifeShear. Under Phase I, a small solid-state diode laser igniter was built and successfully tested. Under Phase II, which is now in progress, they are building a small portable Nd:YAG laser for the cutter. Testing will begin later in the year. Life Shear's use of the LIS device in its commercial rescue cutter product will provide economy of scale and a stable industrial base for the Army igniter.

Some of the advantages applicable to both the cannons and the LifeShear are that the:

- laser fires faster than conventional primer igniters;
- primers contain lead salts, but the laser is an environmentally clean igniter;
- LIS is safer since the optical fiber, is immune to electrical interference and accidental ignition;
- laser can be controlled with a computer, preventing firing before it is properly aimed.

The LIS is now the main igniter for the XM297 ASPA - over 10,000 rounds were fired using the LIS. The LIS was also integrated into the currently fielded Paladin M109A6 Self-Propelled Howitzer. Sales are for 850 units for the Paladin and 1100 for the crusader system.

COMMERCIAL INTENT AND STATUS: The "Life-Shear" was released to full production within six months of the TRP award. Over 600 units per month were being produced for the commercial market place by the end of 1995. This cutter can sever automotive brake pedals and clutch pedals and can cut off the roof posts and pillars to remove the roof of an automobile. Fire departments/rescue workers/police departments are a market for the pyrotechnic-powered cutters. The cutter weighs 70 percent less and is reported to cost 70 percent less than other rescue equipment currently on the market.

Remington Arms, which produces one million firearms, wants to look at laser igniters for gun. The success of this technology is evident by Popular Science Magazine selection of the Hi-Shear cutters as one of the "Best of What's New Awards for 1995." In addition, rescuers at the Oklahoma federal-building bombing used this cutter to help extricate victims.

Quick Reaction Spoken Language Translator (QRSLT) 14030

Language Systems Inc.

BACKGROUND: Misunderstood language or hand signals between U.S. soldiers and foreign civilians or combatants can have unfortunate consequences in both conventional conflict and in operations other than war. For many languages, human translators are unavailable to DoD in the numbers and skills needed. During the Persian Gulf War, the U.S. and its allies captured over 50,000 Iraqi POWs yet could question only a few of them, due to a shortage of translators. Important operational and intelligence information was thus overlooked. As U.S. forces deploy to more crisis zones, the need for automated two-way language translation is growing. QRSLT reduces unnecessary casualties and makes US forces more effective.) Requiring at least a 133-MHz Pentium processor and 32 MB (megabytes) of RAM (random-access memory), QRSLT can be packaged as a wearable or handheld PC-based system for use by soldiers, law-enforcement agencies (LEAs) and social services organizations in communicating with non-English-speaking civilians. QRSLT is speaker-independent, accommodating dialects and regional speaking differences even in acoustically noisy environments, making it ideal for crowd control.

OBJECTIVE: This project addresses a hand-held or wearable two-way language translator that lets soldiers, special-operations forces (SOF) units and civilian LEAs communicate with people who cannot speak or understand English. QRSLT translates simple English queries or statements in real time into a specified foreign language (Mandarin Chinese, Mexican English, French, Arabic, Korean, Russian, etc.), using a high-performance speech synthesizer for the foreign-language output. Similarly, it translates spoken speech in the target language into English and synthesizes a spoken output. The team will demonstrate English/Spanish as its primary language pair and is adding other languages like Arabic as the system's performance and language-pair repertory expands.

MILITARY INTENT AND STATUS: As the first units deployed to crisis areas, SOF units need low-cost, automated two-way translation to deal with prisoners and local civilians. In areas like Bosnia, QRSLT can complements a one-way electronic phrase book used there to help U.S. and allied soldiers communicate with local people about minefields, medical care, and public safety and police issues. *The project met all its goals by its mid-1998 completion. Follow-on funds allowed a Korean/English variant for the Air Force's July, 1998 "Global Patriot" war game.*

While no transition funding is identified, LSI is being urged to bid on an Army Research Office (ARO) program that may use QRSLT. A SOF psychological-operations (PSYOPS) unit at Fort Bragg, N.C., will also test QRSLT. The project is now driven more by LEAs' continuous and predictable translation needs than by DoD's less predictable translation needs, which tend to be keyed to crises.

COMMERCIAL INTENT AND STATUS: Beyond LEAs and social services, targets include large companies serving non-English-speaking populations. *QRSLT is faring well commercially, with very successful beta testing by Los Angeles and Fresno County sheriffs prompting wide interest. The two counties' social services are also interested in using QRSLT.*

Regional Technology Alliance for High Aspect Ratio MEMS (HIMEMS) Technology Development 3798

MCNC (Microelectronics Center of North Carolina)

OBJECTIVE AND GENERAL STATUS: The development of affordable, mass-producible MEMS (microelectromechanical) devices with high-aspect-ratio (HIMEMS) structures (deep trenches, membranes, cantilevers or beams with aspect ratios up to 100:1 and vertical dimensions up to 500 microns) is central to breaking MEMS into commercial, scientific, medical, environmental sensing and defense markets. Such structures allow microsensors, data storage devices, micro pumps and actuators, mechanical transistors, implantable medical monitors and diagnostic lab-on-a-chip. But prior to this project, producing HIMEMS affordably in large volumes with the lithographic methods used in integrated-circuit (IC) fabrication was daunting. The best fabrication process (Germany's LIGA) combines synchrotron-generated X-ray lithography, with metal electroplating and injection molding, but needs powerful synchrotrons for penetrating resists to great depth. Few U.S. synchrotrons have the power and throughput needed for high-volume HIMEMS production. MCNC's HIMEMS Alliance sought to combine LIGA with IC manufacturing methods to create a cheap, vertically integrated, high-volume HIMEMS design and manufacturing process, replacing a high-cost, low-volume precision engineering niche. This distributed HIMEMS base uses three U.S. synchrotrons to make high-aspect-ratio metal molds for mass fabrication of MEMS parts in varied materials by injection modeling, casting and electroplating.

MILITARY AND COMMERCIAL INTENT AND STATUS: Military HIMEMS niches cover many platforms, missions and environments: inertial navigation systems, FS&A (fuzing, safing and arming) devices, lab-on-a-chip sensors for chemical and biological warfare agents (CWA, BWA), optoelectronic identification tags, fiber-optic couplers and multiplex/demultiplex units, and hundreds of other dual use devices. Commercial HIMEMS niches cover textiles, medical care, aerospace, automotive engineering and environmental monitoring. Lead products include implantable drug pumps and mini-motors for powering miniature magnetic-disc drives, high-resolution digital cameras and video, automotive data-storage devices for vehicle navigation and moving-map displays, electrical mini-actuators and pumps, and gyroscopes.

The team's two military applications (FS&A devices for Navy torpedoes and Army artillery shells) and two commercial products (an integrated variable-reluctance minimotor for mini disc drives and an implantable insulin pump) were chosen to drive LIGA-HIMEMS technology, design and production guidelines and to build up a library of HIMEMS material/process combinations, structures and components. The Navy torpedo FS&A unit is a unique, complex assembly with demanding surety features, yet must be produced affordably in single quantities as needed:

impossible with larger conventionally machined metal FS&A devices, which demand dedicated production lines. The mini-motor was the most complex MEMS structure ever built and exercised virtually every LIGA process needed for complex HIMEMS structures.

Despite a one-year delay in start-up, the project performed extremely well. The Department of Energy's Oak Ridge laboratory developed a high-throughput, low-cost automated-array assembly processes to mate LIGA-fabricated components into more complex microsystems. The Navy FS&A design led to enthusiastic Navy baselining of HIMEMS-FS&A for all future underwater weapons, including a new torpedo now under design. The Army's successful design of a HIMEMS FS&A device for 155-mm artillery shells remains stalled by funding shortfalls. Both S&A projects proved that the project's HIMEMS base could produce unique, few-of-a-kind electromechanical devices quickly and at costs that would be impossible to replicate if the assemblies had to be procured as conventional "macro"-scale items from traditional vendors. The Alliance's mini-motor is being evaluated by IBM for next-generation micro-disc drives and other uses. The medical device, now on the market, can be used not only for insulin delivery but for automated release of antidotes to soldiers exposed to CWA/BWA weapons. Another spinoff is HIMEMS piezoactuators with one-micron accuracy for aligning optical fibers for splicing (now costing $4,000 per fiber).

Self Monitoring Advanced Remote Technology System (SMARTS) 16002

Auburn University

BACKGROUND: In transitioning MEMS (microelectromechanical systems) to defense and commercial markets, a major challenge is combining MEMS with low-power electronics (LPE) for MEMS-based health monitoring (HM), alarm sensing and other uses. LPE-MEMS HM devices must lie dormant for years, using very little power, yet quickly power up to record HM events like shock. This project addresses HM technical needs like 5-10 year power supplies; LPE techniques and materials for fast wake-up, data collection and storage; and life-management software for extended life. Embedding such sensors in the weapon or structure allows continuous on-demand tracking of the launch readiness of "wooden round" tactical missiles factory-sealed in their launch containers, as well as the structural health of buildings and bridges. By contrast, current HM practices focus on episodic sampling, tear-downs or firings. In military use, this off-line HM is labor-intensive and generates costly organizational overhead.

OBJECTIVE: The SMARTS project objectives were to combine a 2nd-generation MEMS ("integrated MEMS" or "iMEMS") 3-axis accelerometer chip from Analog Devices Inc. (ADI) with non-MEMS HM sensors to provide HM data for 5-10 years for a Patriot wooden-round air-defense missile. The team planned to build integral wireless RF (radiofrequency) data links, including cellular-telephone link, for SMARTS sensors. It was also to develop similar HM/RF units to monitor bridge cracks and stress, corrosion and road fog and ice.

MILITARY INTENT AND STATUS: SMARTS addresses stubborn problems with wooden-round missiles designed to operate without intrusive maintenance or pre-launch checkout for up to 10 years. Current HM sensors for missile containers monitor only humidity, with no routine monitoring of transport shock, vibration and temperature. Monitoring these three parameters usually requires large, costly customized sensors with hard-wired readout. By contrast, SMARTS sensors fitted to the missile canister can relay such HM data over hard-wired or wireless links for external readout, either on demand or on a preset schedule. This replaces today's relatively wasteful quality-assurance methods such as activation or firing of sample missiles to provide crude HM sampling of a given missile stockpile or production batch. Another SMARTS payoff is in

logistics savings: i.e., no non-functional rounds would be deployed to forward locations. The large data fields produced by intelligent SMARTS sensors also allows predictive maintenance. SMARTS meets Army requirement for real-time HM monitoring of field assets, just-in-time sparing and stocking (focused logistics) and in-transit tracking of equipment in deployment.

The team has fitted SMARTS to a Patriot canister and is collecting data. The team has promoted SMARTS to DARPA for "focused logistics," to the Navy for monitoring ship turbines and tanks and for firefighting, and to the Department of Energy for monitoring nuclear materials. The team is sampling ADI's SMARTS accelerometer internally (to Lockheed Martin and Litton) and is scouting military and commercial LP-MEMS uses. Drawing on military users' reviews, ADI has redesigned its device and is marketing it. The Army program manager is marketing SMARTS to Army force-planning offices for missile containers and ground hardware, for which his recent return-on-investment study of SMARTS HM surveillance found ROIs of 20:1 and 11:1, respectively. He sees Army budget cuts driving the Army to accept commercially driven SMARTS designs.

COMMERCIAL INTENT AND STATUS: SMARTS HM sensors on bridges can collect wide-ranging data on road and weather conditions and structures. Other markets include monitoring food quality and safety, embedded shock recorders in structural members, concrete decks, paint-condition sensors and crack-growth sensors. *The team fitted SMARTS to a Florida highway bridge and is collecting data.*

Short Wavelength Optical Storage 5009

Imation (spinoff of 3M's Data Storage Optical Technology Division

BACKGROUND: Steady gains in data-storage densities on optical discs is a long-standing goal for electronics vendors. The two most widely used optical recording media today (phase-change and magneto-optical media) need high densities to store high-bandwidth data like video imagery and movies, especially long feature-length films. These markets require removable discs that can be rewritten many times, converting optical storage from preprogrammed read-only discs into portable general-purpose discs. To boost data-storage densities, developers need short- or mid-wavelength solid-state lasers offering smaller spot sizes and longer lifetimes; they also need improved optical recording media, disc drives and readout electronics that are compatible with such lasers. DARPA-funded short-wavelength lasers for optical storage contributed to this project, as did Japanese R&D on laser diodes (LDs).

OBJECTIVE: The vertically integrated team initially focused on rewritable media with a blue-green laser, aiming at 10 gigabytes (billion bytes) on a double-sided 5.25-inch disc using magneto-optic materials. This is 5-10 times the capacity of commercially available discs. The team also sought to raise throughput from ~6 million bits/second (Mbps) to 40+ Mbps and to reduce access time to under 25 microseconds. An essential element was demonstration of 10-gigabyte capacity on a low-cost double-sided patterned plastic disc. When the team realized that DVD discs using phase-change materials (vs. magneto-optic) were the emerging low-cost media for consumer markets, it opted for such materials and cut its data-rate target to 16 Mbps to accommodate the slower material.

MILITARY INTENT AND STATUS: This project targeted military high-bandwidth data needing portable forward storage: e.g., archived terrain elevation and feature data for aircraft and cruise-missile strike planning; imagery from airborne sensors; and archived maintenance data for forward aircraft and electronics maintainers. Ending in September, 1997, the team met its 10-

gigabyte storage goal, although the optical source (a Japanese LD) promising the highest storage density will not be available until 1999. The future commercial availability of mature blue-green lasers promises the highest storage density. *The initial defense application will be mission-planning systems for F-15 and F-22 strike aircraft.*

COMMERCIAL INTENT AND STATUS: The movie industry, which makes more money selling its work on prerecorded media than in theater sales, seeks discs that can store feature-length films. Likewise, users of wearable computers and personal viewers demand more data on smaller discs. In commercial markets, capacity growth in PCs and workstations drives a need for removable, rewriteable optical storage on smaller discs. The project's two initial target markets include information servers and computer multimedia. *Pending the availability of the Japanese LED and short-wavelength blue-green lasers, the project will not transition commercially into the highest-density storage markets. However, the project's advances can be used in 4.7-gigabyte DVD discs.*

SiC Power Electronics for Affordable Next Generation Electric and Hybrid Vehicles 17026

Northrup Grumman

BACKGROUND: Military and commercial needs for power switching components include aircraft, ships, and industrial power distribution. Replacing conventional high power devices with semi-conductor technology will allow a significant reduction in size and weight, a huge advantage for military systems. SiC with its high electric breakdown strength offers an ideal semiconductor for power switching. Devices made from SiC will have reduced size and cooling requirements, and increased reliability that will help replace hydraulic systems on aircraft with wires and distributed motors, build more reliable shipboard power distribution systems, and could facilitate a hybrid powered main battle tank with active armor and electric guns. This project advances these goals by addressing critical technical issues in making SiC devices such as packaging, high-temperature and high power operation, and reduced manufacturing costs.

OBJECTIVE AND GENERAL STATUS: The project was to develop a packaged 600V/100 ampere Silicon Carbide (SiC) Metal Oxide Semiconductor turn-off thyristor as a building block for solid-state power controllers. *At this stage of the program Northrup Grumman has developed a number of high voltage, high current SiC devices. They recently tested an assembly of gate turn-off thyristors (GTO's) that functioned up to 40A and simple diodes that could handle in excess of 100A. Withstand voltages exceed 600V while some devices were able to go above 1KV. This performance level is 10 to 100x better than the performance exhibited by similar devices when the proposal was submitted. However, SiC devices operating at 600V and 60 Amps as envisioned in the proposal have not been achieved yet.*

MILITARY INTENT AND STATUS: SiC high power devices will improve the performance of millimeter-wave radar transmitters and electric vehicle systems. While conventional semiconductors have limited temperature tolerance and power density capabilities, cost-effective SiC based power-switching devices would overcome these limitations. SiC power switching devices are important for the Air Force's More Electric Aircraft Program, the Navy's Power Electric Building Block Program, and DARPA's Combat Hybrid Power program. *Northrup Grumman has won a program with DARPA to use SiC devices in an inverter for the Combat Hybrid Power System (CHPS) program.* This program, if successful, will result in device similar to the SiC MOS turnoff transistor (MTO) needed for the next Army After Next vehicle.

COMMERCIAL INTENT AND STATUS: A major area of commercial application is electric and hybrid cars. 3KV/100Amp devices will be available for testing within two years through this project, while 25KV/1000Amps will be demonstrated in about three and one-half years. SPCO is the commercial arm of the consortium. Their goal is to build tens of thousands of these devices per year for the power (utility) industry (EPRI wants a 5KV/1000Amp device). *The commercial prospects are still considered very good by Northrup Grumman. They have signed an MOU with SPCO to commercialize the SiC MTO and have won a Title 3 program from the USAF to do that. The first phase of the Title III program will target a Si MTO followed by the SiC MTO in a four year program. No sales have yet occurred but samples are being produced in this program for potential customer evaluation.*

Solid State Oxygen Generator (SSOG) 1408

CeramPhysics

OBJECTIVE: To develop a prototype of a ceramic-honeycomb system (oxygen ion conductor) to separate oxygen from air and deliver the oxygen under pressure without pumps or moving parts. CeramPhysics, Inc. accomplished this prior to the end of the TRP program, with five prototype demonstrations that exceeded the original program goals.

Twelve modules have now been tested at temperatures in the range 500-650ºC wherein the oxygen-generation rate was measured as a function of the dc current applied (up to 0.6 A/cm). This demonstrated not only that hermetic sealing at the operating temperature was achieved but also that electronic conduction in the ceramic is negligible. One module was put on long-term test at 550ºC. For 320 hours there was no change in the oxygen-generation rate. The honeycombs were stable at large current densities: Two samples withstood 2 A/cm for 24 hours at 600ºC without degradation. The program was very successful, and the demonstrations achieved and exceeded the original program goals.

MILITARY INTENT AND STATUS: *Brooks Air Force Base is applying the technology to generating on-board aircraft breathing oxygen (prototype generators have been provided for in-house testing). New capability: Military aircraft use does not demand bleed air from the engine.*

CeramPhysics also used the ceramic honeycomb technology to demonstrate a fuel cell for DARPA as part of separate $50K project. The fuel cell ran for 100 hours at 600 degrees Centigrade in unreformed methane without sooting. The demonstration was a spin-off from work done on this TRP project.

The technology has been offered to the Army for tanks and armored personnel carriers operating in chemical/biological warfare conditions, since it will extract 100% pure oxygen from an atmosphere contaminated with biological and gas agents, such as anthrax, botulism, and mustard gas. Another potential application is to supply the nitrogen used in the tires of large aircraft (by removing the oxygen from surrounding air, thus leaving a nonflammable mix). The home health care application described below would apply to battlefield care, as well.

COMMERCIAL INTENT AND STATUS: The technology has been licensed to a NetMED, a medical supply company, for application to the home health care market (a $1B per year market) as a low cost oxygen supply system for the home, and is currently in the pre-manufacturing phase. *It is estimated to have a production cost of less than $400 per operating system at a volume of 1,000 to 5,000 units a year. Net MED spent $1.5M over the past two years, including $500K with CeramPhysics.*

NASA is also interested in the technology for the in-situ generation of oxygen from the Martian atmosphere. A small kickoff program from NASA resulted in a successful demonstration that this technology can draw oxygen from the atmosphere of Mars.

Spatial Division Multiple Access Wireless Communication Systems 2110

ArrayComm, Inc.

OBJECTIVE AND GENERAL STATUS: A smart antenna platform was developed by the SDMA consortium in the course of the TRP program. Smart antenna systems are capable of providing balanced uplink and downlink gain and interference mitigation exceeding that possible from conventional methods for distributing and collecting radio frequency energy from space by an order of magnitude or more. The combination of increased base station sensitivity, reduced radiated downlink power and active interference mitigation provided by smart antennas results directly in improved signal quality and increased capacity. The platform developed was specific to the PCS-1900 air interface, the U.S. member of the General Surface Module (GSM) protocol family. Worldwide, GSM is the most widely deployed protocol family with more than 44 million subscribers in 109 countries. This project addressed a key problem for full-duplex GSM smart antenna systems through the development of strategies that resolved this issue.

- ArrayComm designed and implemented all baseband electronics for the platform, consisting of two boards on which the spatial and temporal processing functions were implemented and a board which provided a network interface to standard telephone handsets and to a PBX. The two principal boards each contained a general purpose processor block based on an embedded version of the DEC Alpha RISC processor and multiple AT&T and Motorola DSP's (16 DSP's on one board, 17 on the other). On each of these boards, the general purpose processor communicated with the DSP's via an on-board PCI bus with PCI controllers of ArrayComm's design. These boards are representative examples of commercially viable high-performance designs for smart antenna processing which can be economically realized by use of off-the-shelf components.

- ArrayComm designed and implemented all software for the demonstration platform. In addition to software for the general purpose processor and for the DSP's in support of the spatial processing and GSM protocol processing mentioned above, ArrayComm implemented all base station control and user interface software and all of the code necessary to control the other consortium members' hardware. ArrayComm also ported Wind River System's VxWorks operating system to the Alpha-based general purpose processor.

- Execution of systems integration function. ArrayComm acted as systems integrator for the project. In addition to test, integration and debug for all of the consortium members' components, ArrayComm worked with an antenna manufacturer (Allgon Systems) to design and build an antenna array for use with the platform. ArrayComm also designed and executed the field tests for the program.

MILITARY INTENT AND STATUS: Arraycomm states that, "For our project, the key benefit of dual use was really one of conversion of defense technology. Although ArrayComm has always been a commercial company, Watkins-Johnson, one of the other consortium members, is a well established defense contractor and the dual use/conversion aspect of the TRP program gave them

an entree to leverage some of their military technology for a commercial application. Although there may be potential military applications of the technology developed by the consortium, Watkins-Johnson's wideband radios in particular, the consortium's principal focus was on commercial applications."

The military would buy this product from the shelf. It is a spin-off of military technology, rather than a spin-on of commercial technology to the military. Although there may be potential military applications of the technology developed by the consortium, Watkins-Johnson's wideband radios in particular, the consortium's principal focus was on commercial applications.

COMMERCIAL INTENT AND STATUS: *Arraycom is in active discussion with its manufacturing partners. There is no doubt that a commercial market exists for smart antenna systems designed for GSM. Because of the small size of the company, they believe their only chance of entering this market is as a partner to an existing manufacturer who already has market presence and the required sales and distribution channels. They indicated that they are talking with a number of potential partners, but have no firm GSM agreement with any partner at this time. They believe that high quality field results recently obtained provide considerable additional credibility to their position in these discussions.*

Surgical Simulation for Limb Trauma Management 1973

MusculoGraphics, Inc.

BACKGROUND: The company was formed to help satisfy the growing need for highly accurate computer models of the human body. MusculoGraphics teamed with Medical Media Systems (Hanover, NH) and the Rehabilitation Institute of Chicago (Chicago, IL) on a two-year TRP project to develop a surgery simulator for limb trauma management. The initial strategy was to develop a model for a single type of penetration wound to the lower leg and extrapolate successful algorithms and software applications to other anatomical examples. Using magnetic resonance imagery, photographic data, and volume-rendering software, a preselected injury can be generated, with which the medical trainee can interact in real time. Static and dynamic displays of skin, bone, muscles, ligaments, blood vessels, and nerves of the leg will be represented, allowing realistic surgical procedures to be performed and their effectiveness assessed.

OBJECTIVE AND GENERAL STATUS: The goal of this project was to develop the first anatomically correct, three-dimensional computer visual model of a human limb for high fidelity surgical training with tactile feedback. This project is designed to significantly reduce surgical training costs and the dependency of training on the availability of animal subjects. The tools will be independent of the particular computer platform or user interface. The modeling techniques will be generalized to serve as a framework for a dynamic computational model of the entire body. The team consists of MusculoGraphics, Rehabilitation Institute of Chicago, Medical Media Systems, and Dartmouth-Hitchcock Medical Center.

MILITARY INTENT AND STATUS: The system was developed because there are significant problems with the current methods of training combat medics to treat limb trauma. Problems with the current methods of training combat medics to treat limb trauma include the necessity of animal-based training, which is expensive, troublesome, and does not represent the human anatomy. The consortium has demonstrated feasibility of computer training by building a 3D model of a thigh, based on medical data and a representative gunshot wound, and adding virtual medical tools to assess and treat the injury. The tissues deform, cut, and bleed appropriately when manipulated by

the virtual tools. They are now collaborating with other companies to develop accurate anatomical and physiological models of gunshot wounds and to integrate force-feedback into the system so that the user can feel as well as see the casualty.

An Alpha version of the Limb Trauma Simulator (LTS) was delivered to the Special Operations Medical Training Center (SOMTC) at Ft. Bragg. MusculoGraphics, Inc. worked closely with the medical instructors to integrate the simulator into the curriculum. LTS-alpha allows course instructors to experiment with the system and to develop course curricula around this new simulation technology. LTS-alpha will contain most of the important features of a practical training system, except for force feedback. Recently, MusculoGraphics installed a beta version of the LTS available at Ft. Bragg and two at the Uniformed Services University of Health Sciences. Both are being used, but were not purchased by the DoD. LTS-beta systems test the visual, tactile, and surgical training effectiveness of the simulations.

COMMERCIAL INTENT AND STATUS: LTS can be used in civilian health areas such as disaster response, emergency room medicine, and commercial telemedicine. This technology could also benefit the commercial design and development of minimally invasive surgical techniques. Benefits include the training of medical staff to treat traumatic injuries via simulation technology and supporting telesurgery.

A commercialization plan is in place - Medical Media Systems Inc. are to provide matching funds, their parent corporation, Baxter Healthcare Corp is incorporating this in their plans to commercialize a virtual reality surgical simulation system. A commercial sale of the LTS was made to Hong Kong Polytechnic University. More prospects are being considered. MusculoGraphics is supporting and marketing the system, but not its further development.

System for Noninvasive Arterial Blood Gas Measurement 3184

Rio Grande Medical Technologies, Inc.

BACKGROUND: This TRP consortium is developing biomedical sensors capable of non-invasive blood chemistry measurements that will aid medical professionals in rapid, simple, accurate and low-cost diagnoses. These sensors can accelerate the pace of life-saving medical and surgical care by reducing the turn-around time required for traditional blood chemistry analysis; reduce or eliminate errors associated with sample handling; improve accuracy of analysis where invasive procedures are inherently limited or flawed such as in pediatric care; and reduce risks associated with invasive procedures. Some of the core technology has evolved from research on the non-invasive, non-destructive testing of nuclear weapons conducted at Sandia National Laboratories.

OBJECTIVE AND GENERAL STATUS: To demonstrate the feasibility of a recent technical breakthrough that will enable non-invasive arterial blood gas measurements. One of the most important measures of a person's health status when undergoing critical care or trauma is a complete analysis of arterial blood gas parameters. Today's invasive methods used to obtain this information are dangerous to the patient and burdensome to the physician. Furthermore, presently this data can not be obtained continuously or in real time, but usually takes at least 30 minutes between the taking of blood samples and the receipt of analysis from the laboratory. *The consortium has demonstrated the ability to make accurate, noninvasive, arterial blood gas measurements on animals and humans. An infrared (IR) spectaphotometer was modified to be capable of the accuracy and algorithm needed for this application. The remaining difficulty lies*

in the need to have algorithms to compensate for person-to-person differences. The consortium is also completing work in calibration maintenance, tissue sampling and instrument miniaturization preparatory to detailed human trials.

MILITARY INTENT AND STATUS: Non invasive monitors would eliminate the need to draw blood from the wounded at or near the battlefield, thereby reducing costs, waste, and limiting the incidence of infection from blood-borne pathogens. In a battle setting, such tools could greatly aid medics in making crucial health care decisions and interventions significantly sooner than present practice allows. Such capability could reduce the morbidity and mortality of combat casualties. *Realization of this technology for military use will happen after clinical trials are conducted for civilian applications.*

COMMERCIAL INTENT AND STATUS: The ability to identify the status of a trauma patient in the field, in the emergency room, or in the medical intensive care unit could help drive down costs and increase the quality of care. Arterial blood gas measurements are vital to numerous surgical and critical care procedures. This new technology permits measurements to be taken continuously, without risk of infection and at greatly reduced cost. The technology will be useful in major disasters, where many injured individuals must be diagnosed and treated rapidly and simultaneously. Initial market estimates for arterial blood gas measurement suggest 135 million tests may be administered annually in the civilian sector alone. These sensors may be used in surgical and step-down units; post-operative and cardiac care units; emergency rooms; medical wards; and outpatient settings. Benefits to the military and civilian are strongly overlapping and clinical demand for the new capability has arisen where few high quality alternatives exist (i.e. pediatric subspecialty of pulmonary care). *Despite major advancement, the realized instrument is not yet ready for clinical testing. For continued development, second stage funding, that is three times the TRP funding, has been obtained from a major, global company in the medical field.*

Technology and Productization Acceleration of Low Cost, Aluminum Nitride Electronic Packaging 5095

Raytheon (formerly Hughes Aircraft)

BACKGROUND: The consortium was formed to develop an aluminum nitride (AlN) substrate manufacturing process at a lower cost to match that of lower performance alternatives. AlN has ten times the thermal conductivity of alumina, the material currently used for most ceramic packages, and a coefficient of thermal expansion which is well appropriate to silicon chips. These properties will enable the production of low-cost ceramic packages which support the very large, high power, high pin-count, area-array chips forecast by the semiconductor industry for leading edge microprocessor and application specific integrated circuits as well as military Transmitter/Receiver (T/R) modules.

OBJECTIVE AND GENERAL STATUS: The purpose is to achieve high-volume production of aluminum nitride-based packages at a cost which is competitive with existing lower-performance, alumina packages. The vertically integrated team was to develop the low cost processes and equipment for powder synthesis, sintering, and plating driven by the needs and product evaluation vehicles provided by a military and commercial end-user team. Specific goals of the program were: to demonstrate the electroless Au process on AlN, plus significant cost reductions in processing; integrating these improvements in manufacturing prototype T/R modules for defense applications, and delivering the initial prototype T/R modules to Hughes. *A major*

accomplishment of this project was the lowering of the processing temperature of cofired AlN packages from 1850C to 1550C so that the infrastructure established for cofired Al2O3 packages, processed at 1450C, can be used for AlN. The achieved thermal conductivity for AlN of 150W/m-K is even better than that of silicon at 120W/m-K and much better than the 20W/m-K inherent to alumina. Dow Chemical developed a U.S. source of AlN powders but it is not yet at the quality that is available from Japan. Carborundum and MIT have been developing an improved metal conductor plating process, while a comprehensive cost and processing model has been developed at Harvard. Initial prototype T/R modules have been delivered to Raytheon (Hughes) for qualification.

MILITARY INTENT AND STATUS: AlN multilayer electronics substrates offer significant advantages in heat dissipation over alternative materials for high power electronics applications. These include radar T/R modules such as are being used for the F22, JSF and F-18 retrofits. The thermal properties of AlN allow higher performance, and more reliable radar systems. *Transition may happen via programs such as DARPA's High Density Microwave Packaging (HDMP) program, packages developed at IBM; prove out the 3D stacked T/R module concept. It dissipates 50W/in**2 to the cold plate, comparable to the latest Intel processors. One layer has the high power amps; one the driver amps, and one the controls. This structure is developed to go into the next-generation phased-arrays; lowering the cost by 15% as compared to the same module built in "brick style." In addition to the original 3000 unit.*

COMMERCIAL INTENT AND STATUS: Carborundum Corp., the original lead company on this project, was responsible for developing the commercial market for AlN substrates. The higher cost relative to alternatives was slowing its commercialization. The TRP effort was expected to allow Carborundum to achieve the lower cost goals that were needed to accelerate commercialization. *During the course of the TRP, Carborundum Microelectronics Corporation was been sold twice, has had two different presidents, and on the last sale to Crystalline Materials Corporation lost everyone in its upper management. This necessitated a no-cost extension and the cost goals have not been met. Lower cost AlN powders, made by a direct nitration process, and a low-cost sintering process are still in development during the third year of this TRP.*

Technology to Produce High Performance/Low Cost Interconnections for Flip Chip Attach 3327

IBM Corporation

BACKGROUND: The synergistic combination of materials, processes and equipment development capabilities of the consortium is expected to achieve commercialization in three years. A low cost, high performance flip-chip attachment (FCA) adhesive interconnect assembly process that is lead-free was to be produced in 1997.

OBJECTIVE AND GENERAL STATUS: The consortium's purpose was to develop isotropically electrically conductive adhesives to form high performance interconnection for FCA for the semiconductor electronics packaging industry. This technology will produce an order-of-magnitude improvement in manufacturing labor hours over current solder-based systems. Specific objectives include lower cost/higher volume manufacturing, environmentally safe materials (lead free), and higher density assemblies. *IBM has demonstrated engineering feasibility and is in the process of building hardware for qualifying the base technology for internal use. The effort has*

demonstrated an approximately 20% cost reduction in achieving FCA on 250 to 350 input/output (I/O) integrated circuit chips.

MILITARY INTENT AND STATUS: This project was expected to achieve significant cost savings for the military without compromising performance. For example, one of the goals was low cost assembly, while meeting the aggressive military reliability requirements so that the military could use COTS parts. In addition, the proposed flip-chip attachment material had been shown to have excellent contact resistance stability even when immersed in liquid nitrogen, illustrating suitability for applications in spacecraft - again at low cost. *At the present time there are no commercial sales and thus no military utilization, since that can happen only through commercialization.*

COMMERCIAL INTENT AND STATUS: The industry estimate was that a $4.8 billion market would exist in this technology by 1997, leading to initial marketing projections of an opportunity to sell 133 manufacturing lines starting in 1996 (capturing 5% of the total world wide market for FCAs). The estimate of the number of manufacturing lines increased to 967 by the year 2000, capturing 25% of the worldwide market for FCA that is expected to reach $11.9B by the year 2002. The revenue projections were as high as $1.17 billion for capital (line equipment) and $1.74 billion for the assembly processes. *The highly optimistic predictions of sales have not been realized in that time, Universal Instruments, a consortium member, is adapting processing hardware that will apply the conducting adhesive to its General Surface Module (GSM) platform. A private consortium of 30 companies has been formed to evaluate the GSM for their use and of these some 3 to 5 companies are likely to be interested in incorporating the conductive adhesive applications module. Sales are now expected in two years. Negotiations to license the adhesive for volume manufacture broke down between the first candidate company and IBM. IBM is now pursuing a possible licensing agreement with two other companies.*

Testbed for Digital Wireless Communications and Networking Systems 13012

Lucent Technologies

OBJECTIVE AND GENERAL STATUS: The Wireless Interworking Testbed Team, led by AT&T and including the Army's primary communications R&D center (CECOM), will establish an interoperable, end-to-end, mixed wireless and wireline testbed for demonstrating and validating new technologies and standards. This will improve the ability of both the DoD and the commercial sector to develop, integrate, test, and buy new combinations of digital wireless products and technologies. In particular, projects performed within the testbed will accelerate the adaptation of commercial communications standards and products for military uses. Additionally, the testbed will lend itself to the development of large-scale commercial applications such as video-on-demand services that could set the trend for the video distribution systems of the future.

MILITARY INTENT AND STATUS: This project is expected to provide military access to state-of-the-art emerging commercial technologies in the area of wireless communication and networking. The commercial technologies tested in this testbed are all potential candidates for transition. *But, there is little prospect for direct commercial success, since this is a testbed.*

COMMERCIAL INTENT AND STATUS: The project will expand the marketplace for new technologies, services and products in the area of wireless communication and networking, and expand testbed capabilities without investing millions of federal dollars. *Commercial integration of the testbed has been almost non-existent, nor have the TRP consortia companies made the*

testbed part of their core marketing. Some of this is attributed to the fact that the commercial data market has not developed at the rates originally projected.

TI/Raytheon 'Leap-Ahead' Approach to U.S. Flat Panel Display Competitiveness - Field Emission Displays 5048

Raytheon (bought Texas Instruments (TI))

BACKGROUND: Assuring the commercial availability of affordable, high-performance flat-panel displays (FPDs) has concerned DoD for over a decade. The growing information intensiveness of combat makes the display a central factor in the combat performance of soldiers and airmen. Such displays face unique requirements for broad temperature range, sunlight readability, shock resistance, maintainability in harsh environments and power draw. DARPA's High Definition Systems (HDS) program funds leading-edge R&D in helmet-mounted displays (HMDs) and larger displays, from desktop/laptop size to command-post size (e.g., 120-inch diagonal) FPDs. DARPA seeks improvements in life-cycle cost (LCC), mean time between failure (MTBF), weight, ruggedness and power efficiency. Yet DoD cannot afford the high unit prices of small production runs of military-unique FPDs that have no domestic demand. Also, with most U.S. computer integrators buying their FPDs, including top-of-the-line AMLCD (active-matrix liquid crystal display) FPDs, from Asian vendors, DoD worries about offshore monopolies in FPDs. This drives it toward dual-use FPD options and next-generation FPDs that match or outperform AMLCDs but are domestically producible. DoD has strongly supported FEDs (field-emission displays). Like CRTs (cathode ray tubes), FEDs use cathode emissions, but employ millions of tiny cathodes rather than the CRT's one large cathode.

OBJECTIVE: Using a French FED design, the team sought lower manufacturing costs, better packaging and more power efficiency to boost FED marketability. TI would pursue small military and commercial FEDs; Raytheon would stress a high-brightness FED for military and commercial aircraft and for high-end commercial niches that need full sunlight readability, high brightness, and a wide viewing angle. Raytheon's production would begin with low-volume military production, followed by high-rate commercial production. This "low-high" strategy contrasts with the "high-low" plan of another TRP-funded FED contractor (Candescent), which starts with high-volume commercial markets to drive down production costs for later low-rate military production.

MILITARY INTENT AND STATUS: *This project failed despite meeting all its development milestones within budget. TI exited early in the project and was replaced by Lockheed Sanders. Raytheon began with a 6-inch monochrome FED, which it tested in an F-16 head-up display (HUD) that replaced a Raytheon CRT. It now makes 4-inch color FEDs and invested heavily in a high-volume production line.* But it ran into vacuum-sealing problems: a major issue for FEDs, which need high-quality vacuum. In May 1998, *Raytheon told DARPA it would exit the FED business and focus on integrating systems rather than developing components. DARPA urged Raytheon to sell its FED line to another vendor, but this has not occurred. The Air Force and the U.S. Special Operations Command have approached Raytheon about an FED purchase. Lockheed-Sanders also wants to fit the F-16 HUD to a large buy of F-16s ordered by the United Arab Emirates.*

COMMERCIAL INTENT AND STATUS: *No markets were targeted and the project has stopped.*

Turboalternator for Electric Hybrid Vehicles 2690

Allied Signal

OBJECTIVE AND GENERAL STATUS: This project features a small high-performance gas turbine with a high-output permanent-magnet (PM) generator/motor mounted on a turbine shaft. This design draws on earlier turboalternator R&D funded by a federal interagency "Partnership for a New Generation of Vehicles" (PNGV) program for a midsize hybrid-electric vehicle (HEV) and also on an Allied Signal-funded under-armor APU (auxiliary power unit) for the Army's M-1 tank. The low-part-count design allows high power output at low weight, eliminates costly gearing and its related lubrication and maintenance, and uses non-oil air bearings for unlimited shaft life. As a compact APU, it lets a crew shut off the M-1's main gas turbine in "silent watch" mode, cutting its infrared and acoustic signature and fuel consumption. It can power a growing array of M-1 electronics and feed bleed air to an "overpressure" system protecting the crew compartment from nuclear, biological or chemical weapons. It can also be used in aircraft and shipboard APU's; in mobile generator sets (gen-sets); and in military or commercial HEVs that combine diesel- or turbine-driven motor-generators with electric-energy storage and electrically driven axles or wheels. For HEVs, it can add a catalytic combustor for low emissions and a recuperator for added efficiency. The latter can extract thermal energy for heating or cooling buildings ("cogeneration") when the turboalternator is used commercially for on-site or "distributed" power generation.

MILITARY AND COMMERCIAL INTENT AND STATUS: *The project was a technical success in all respects. The team of California's CALSTART HEV/EV consortium and Allied Signal sought a 10-kilowatt (kW) variant of the M-1 APU, with four goals in mind: refining the under-armor APU, developing a low-cost HEV variant and demonstrating it as a range extender for an electric-drive bus, and developing a ultra-low-emission clean-burning combustor. However, the Army chose another turboalternator for the M-1 APU, while the PNGV program opted for a clean-burn diesel and geared generator rather than this project's integrated turboalternator for its PNGV prototype, set for 2004. Yet the project found an unexpected fast-growth commercial mass market in on-site generation. Allied Signal is producing over 40,000 units/year for an Illinois utility serving eight states. The product improvements, producibility advances and improved components from this market allow a quick-reaction production base for dual use HEV and gen-set variants. The technology is in review by service planners for non-armored and armored vehicles like the Marine Corps' Advanced Amphibious Assault Vehicle (AAAV). The team also is scouting niches in PNGV-class cars and low-emission commercial trucks.*

ULTRA 5135

Inframetrics Inc.

BACKGROUND: This is one of three competitive efforts to develop an inexpensive and effective uncooled infrared imaging system. This effort is based on the monolithic microbolometer sensor technology initiated by the Honeywell Technology Center.

OBJECTIVE AND GENERAL STATUS: The TRP consortium was to provide a low cost infrared sensor that would include the microbolometer infrared detector, read-out electronics, and a unique detector package. These components were to be integrated into an established commercial camera design and to be evaluated for applicability in various military systems. *Most of the technical specifications that were set out at the beginning of the program have been met. However, wafer level packaging has not jet been transferred out of the laboratory. This latter fact causes the focal planes to still be somewhat more expensive than originally estimated. The cost has been reduced from the $15,000 to $20,000 range to $3,300 when bought in quantities of 3000; the original estimate was that the cost would get down to $1000 per focal plane.*

MILITARY INTENT AND STATUS: The military benefits from the incorporation of low cost, uncooled infrared sensor products will be realized in submunitions, missile seekers, missile warning receivers and mine detection. *Military evaluations of the focal plane have been conducted for use in helmet mounted mine detection systems, BAT sub-munitions, for terminal guidance for Navy's DAMASK program, and as part of a sensor suit for the C-17.*

COMMERCIAL INTENT AND STATUS: The uncooled infrared sensors will be used in commercial applications such as predictive and preventative maintenance, process control, non-destructive testing, fire fighting, search and rescue, perimeter surveillance, boarder patrol, urban police tasks and collision avoidance. *Boeing/Rockwell, a partner in this consortium, has commercial orders from four different customer that will use 7000 focal planes in the next two years and Inframetrics plans to sell between 500 and 1000 uncooled radiometers per year that also require the Boeing/Rockwell IR focal planes.*

Uncooled Infrared Sensors 5093

Raytheon TI Systems (RTIS)

OBJECTIVE AND GENERAL STATUS: The objective of this project was to develop a series of IR sensor system products (as opposed to components or technologies) that are applicable to the military and commercial world without major modifications. Two and one-half years after beginning the TRP project, there are ten different configurations under the Nightsight™ family of sensors systems.

MILITARY INTENT AND STATUS: Military involvement in this project has definitely paid off. For instance, if the project were aimed strictly at the commercial market, rather than being conducted as a dual use effort, the thermal stabilizer (by Marlow) would not have been sufficiently rugged for military use. *Most importantly, the project has already transitioned products to the Army: the Series 200 sensor systems, for military base security, and the Driver's Vision Enhancement for utility and driving use. It also has excellent potential to provide rifle night sights during the next few months. Assuming a ten year military procurement of 30,000 units,*[38]

[38] Market projection by RTIS -- See Questions 1.C., to follow, for details.

the results will be greatly increased night operation capabilities, and a potential savings of $650M over buying either cooled IR or the earlier LOCUSP model.[39]

The Nightsight™ products were tested extensively during qualification tests roughly equivalent to (and sometimes more stringent than) normal military qualification tests. For example, DVE passed military specifications for reliability through demonstration and field tests. The products have done very well and was modified to accept improvements as a result of test results. The thermal stabilizer designs, by Marlow (a consortium member), have all been tested and have met requirements. The military R&D community (DARPA, NV&ESD, Sandia National Laboratories, Naval Criminal Investigative Services, Rome Laboratory) has been involved in the project, partially to enhance transition potential. The project has a Technical Advisory Board (TAB), which has been very successful. For example, the FBI made several changes to the program through the TAB (e.g., adding interchangeable lenses, commercial batteries). Marlow indicated that the military services had been involved in their developments, and that the military needs were the primary drivers and direction-setters.

COMMERCIAL INTENT AND STATUS: The primary focus of the consortium is commercial applications, although their initial customer base is the military. According to a market consultant firm, Frost and Sullivan, the market forecast projected a doubling of the IR sensor market from $660M in 1994 to more than $1.4B in 2001. Marlow believes that the market potential for thermal stabilizer devices is approximately $50M annually. Applications addressed by this effort will include drivers' aid for commercial cars, trucks, ships and boats; covert surveillance and weapon sights for law enforcement agencies; and physical security of facilities, such as buildings, ports, airports and prisons.

The consortium's customers fall into two broad categories based on their needs (observation/detection or driving/navigation) and include Police/law enforcement, USMC, driving aids (eventually), and heat measurement tasks. Over 700 DVE and approximately 200 PalmIR units have been sold. Raytheon now markets PalmIR for $13,000.

NOTE: Importantly, an overarching component of RTIS's strategy hinges on a factory completely free of both military standards and specifications and the conventional defense approaches to production, instead using performance specifications and best commercial practices (such as ISO 9000 for quality control). RTIS began this initiative on their own in 1992 because it had become clear that the cost of maintaining military standards and specifications was driving their costs beyond an acceptable level (this became obvious when the LOCUSP program fell behind schedule and over budget). Government supporters of RTIS's decision to adopt commercial practices in their development process included NV&ESD and DARPA.

[39] Derivation of potential savings is very difficult. In this case, three scenarios were considered, each using an assumed military market of 30,000 that was furnished by RTIS. In the first scenario, the difference in cost of furnishing these 30,000 devices for a unit cost of $30K (LOCUSP) and $8K (Series 200) was calculated. Scenario 2 assumed a lower price for both LOCUSP (due to producibility improvements) and a mature NightDriver (expected to be eventually produced for $500 each). Finally, A comparison was made between the Series 200 and a cooled system, although life cycle cost savings connected with the maintenance of cryogenic coolers was not performed.

Uncooled IR Microbolometer Sensor Cost Reduction Program 5054

Lockheed Martin Infrared & Imaging Systems

BACKGROUND: This is one of three competitive efforts to develop an inexpensive and effective uncooled infrared imaging system. On the CIRUS Program, Lockheed Martin had invented an uncooled sensor consisting of an advanced infrared detector integrated with digital processing on the sensor chip. This sensor "engine" provides a twelve bit output formatted to be compatible with commercial and military imaging systems. The digital, integrated solution to infrared sensing broadens the application base of uncooled infrared sensors, and facilitates the integration of the sensor engine into the imaging system.

OBJECTIVE AND GENERAL STATUS: To develop high sensitivity uncooled infrared sensors, innovative manufacturing techniques for low cost, reflective optics, and modularized electronics common to families of uncooled infrared sensors. This is an integrated solution for reducing the cost of uncooled infrared systems applicable to both military and commercial markets. The Lockheed Martin-led consortium has demonstrated a monolithic uncooled focal plane array camera with the industry's first digital read-out. The uncooled sensor consists of an advanced infrared detector integrated with digital processing on the sensor chip, which provides a twelve-bit output compatible with commercial and military imaging systems. Both the monolithic sensor and the digital read-out add sharpness and fidelity to the image, not previously seen in uncooled sensors. *Cost reduction, as well as size reduction has been implemented for both the infrared sensor focal plane, as well as for the readout electronics. The mean-time-before-failure of this uncooled IR imaging technology has been shown to be greater than 10,000 hrs. The units also become operational in less than 30 seconds from a room temperature turn on. The latter two characteristics are of particular importance to the military user. The system has been delivered to both commercial and military customers for field evaluations, which include extensive user interactions and quantitative evaluations.*

MILITARY INTENT AND STATUS: The military benefits from the incorporation of low cost, uncooled infrared sensor products in submunitions, man-portable weapon sights, helmet mounted night vision goggles and mine detection systems. *The results achieved on this project have enabled the arrayed bolometer-based, uncooled infrared imaging technology to compete for applications previously restricted to the expensive cooled (170 to 190 K) technologies. Successful demonstration of images with the Driver's Viewer Enhancement system at the Aberdeen Proving Ground has qualified the consortium to bid for the upcoming U.S. Army procurement for a Thermal Omnibus that will consolidate the Army's needs for all types of thermal imaging. This Lockheed Martin 240 by 320 uncooled infrared imaging array has also undergone four rounds of testing on MOE Bradley Fighting Vehicles (BFVS) at the Army's Aberdeen Proving Grounds. The industry's first digital interface also facilitates communication of image information among different sensors on the battlefield, and from remote platforms. Ten mine detection units and two thermal weapons sights have been delivered to military developmental systems programs.*

COMMERCIAL INTENT AND STATUS: Commercial products include process monitoring, energy conservation, hazardous material handling, fire fighting equipment, environmental safety, security, border patrol, traffic monitoring, thermal process control, and predictive maintenance. New applications may include facial recognition, machine vision, medical imaging and use of uncooled infrared imaging in space systems. *The uncooled sensor camera has been incorporated into AGEMA's Thermovision 570 system, a system for measuring and analyzing temperature in industrial application. The entire system sells for $46,000. At the present unit cost a sales volume*

of 500 to a 1000 units per year is expected for the next two years. The marketing for these units is being done primarily by AGEMA and Econolite, Lockheed Martin's consortium partners.

UV DIAL (Ultraviolet Differential Absorption LIDAR (Light/Laser Detection and Ranging)) 5043

Litton Amecon

OBJECTIVE AND GENERAL STATUS: DoD is developing versatile standoff sensors called lidars (laser/light detection and ranging) that can monitor chemical aerosols for site remediation or detect chemical and biological warfare agents (CWA, BWA) on battlefields. This project originally sought an ultraviolet differential-absorption lidar (UV DIAL) for BWA sensing. UV DIAL devices send out laser pulses of two slightly different frequencies over wavelengths of 0.25-0.35 microns. When the pulses hit a cloud of biological particles, they cause the tryptophan in such particles to fluoresce, a signal detectable by the lidar's detection optics. The cloud's absorption profile can be screened for uniformity (indicating a man-made bioaerosol) or other features. Competing infrared (IR) DIAL backscatter lidars, working at 3-5 microns, were built to sense CWA from the air in the 1991 Persian Gulf war. IR DIAL offers better range but detects many non-targeted (i.e., non-CWA/BWA) aerosols, resulting in noisy signals. UV DIAL suffers far less in noise, sensing BWAs at 1-2 kilometers (km) and CWAs at 10 km. While no database exists for tryptophan-fluorescence signatures, complicating discrimination of BWA and non-BWA aerosols, UV DIAL does well in characterizing airborne chemicals and CWAs and is commercially and militarily attractive for such uses.

This project was a Los Alamos National Laboratory (LANL) spinoff technology set up to promote UV DIAL. It was originally planned for field measurements of airborne bioparticle size for the Army, complemented by a commercial chemical-emissions sensor for industries and transportation zones regulated by the 1990 Clean Air Act Amendments (CAAA). But the military focus stopped shortly after contract award when the Army chose not to pursue UV-DIAL as a BWA sensor and the prime contractor left, to be replaced by Litton Amecom. The new team opted for a CAAA-oriented chemical sensor. This sensor also interests urban traffic managers, who could map emissions from slow-moving vehicles in high-traffic zones as an indicator of congestion. Another use is monitoring natural-gas pipelines, where leaks are hard to find.

MILITARY AND COMMERCIAL INTENT AND STATUS: *Despite its turbulent start, the project was a partial success but the lidar is now on hold. Litton built and field-tested a solid-state UV DIAL system that combined diode-pumped lasers with nonlinear tunable light sources in a compact, rugged system needing little calibration. The team has been promised funding by the Army Chemical and Biological Defense Command when the sensor is operational. The Army appears reluctant to invest in it, seeing DoE's CALLIOPE counterproliferation lidar offering similar capabilities at lower cost and risk. Other possible users are DoD's Office of Counterproliferation and the Joint Program Office for Biological Defense. For commercial CAAA-based markets, the sensor must pass rigorous and costly EPA certification for use as a "continuous emission monitor" (CEM) on smokestacks. Complicating the picture is Litton's interest in leaving the lidar business, which fits poorly with Litton's core business.*

Vehicle Management System Integration Technology for Affordable Life Cycle Cost (VITAL Program) 10022

McDonnell Douglas Aircraft

BACKGROUND: Given the increasing service lifetimes expected of military and commercial aircraft, the design and support of their flight control avionics (termed their "vehicle management system" or VMS) becomes a significant factor in aircraft life-cycle cost (LCC). In order to reduce aircraft LCC, operators must be able to quickly and cheaply replace aircraft controls that have become obsolete and unmaintainable. However, given the thousands of commercial transports and military aircraft in service today, it is critical that VMS designs embrace a digital "open architecture" that allows use of different components designed for plug-and-play compatibility.

OBJECTIVE AND GENERAL STATUS: The VITAL projects extends plug-and-play compatibility engineering practices -- now used widely in such commercial sectors as personal computers (PCs) -- to dual use aircraft VMS designs. Another crucial benefit of this architecture is that it allows the fitting of new aircraft or the retrofit of select older aircraft with fly-by-wire (FBW) electronic links for VMS communication or fly-by-light (FBL) optical links.

MILITARY INTENT AND STATUS: *DoD anticipates that VITAL's plug-and-play design will cut costs considerably over even the most modern VMS. Benchmarked against the F-22 VMS, VITAL is expected to reduce LCC by 23%, acquisition cost by 29% and "operation and support" (O&S) costs by 20% VMS. Much greater savings would be realized for older aircraft. The fact that VITAL accommodates advances from non-aircraft controls and electronics also gives VITAL more access to the commercial sector. McDonnell Douglas Corporation will test VITAL requirements, standards and components against new-start fighter aircraft like the JAST* (Joint Advanced Strikefighter), as well as fighter aircraft now in production (specifically, McDonnell Douglas-built fighters like the F-18, F-15 and the AV-8B). VITAL will also be tested on two transport aircraft built by the company, the C-17 and MD-90 and -95, and on the company's AH-64 Apache helicopter for the Army.

COMMERCIAL INTENT AND STATUS: McDonnell Douglas sees a potential commercial new-transport market that exceeds 14,000 aircraft through 2011, along with more than 7,500 military aircraft, for a total VITAL insertion market exceeding $1,200 billion.

Virtual Endoscopy 12027

General Electric

BACKGROUND: Virtual endoscopy (VE) combines virtual reality (VR) technology with large 3-D volumetric data sets generated by helical computed tomography (CT) and magnetic resonance imaging (MRI) scanning of hollow organs, as well as ultrasound and laparascopic-video data. This gives doctors a rapid, non-invasive 3-D endoscopic view of patient anatomy without resorting to real endoscopy. VE is especially useful for viewing hollow organs like the cranium, sinuses, bronchi, blood vessels, stomach and colon. It lets surgeons identify organs through a segmentation process and "fly through" the patient's body and organs for viewing them from within. VE imagery presented on a transparent, easily used intuitive display can be used for patient diagnosis, surgical navigation and MIS therapy at local and remote sites. VE thus is a cost-effective, affordable alternative to conventional invasive ("open") surgery. Its techniques can be extended to "virtual

biopsy" in which surgeons "cut away" and measure virtual samples, whose changes in shape and size can also be monitored.

OBJECTIVE: This project is developing software for creating 3-D visualizations and models of patient anatomy from non-invasive imaging. A collateral goal is creating a "critical mass" for VE commercialization by teaming the four major U.S. VE proponents. Fast commercialization of VE would come through GE's medical imaging products group: effectively an internal market for the team.

MILITARY INTENT AND STATUS: *The full transparency between military and civilian uses of VE means that the services can buy VE hardware as COTS.*

COMMERCIAL INTENT AND STATUS: The project has met its goals. *The team is marketing a first-generation limited-performance navigation product ("Navigator") as an adjunct to other data sources. The team will sell three more products through 2001: virtual colonoscopy, which displays the colon's surface and offers limited local fly-through; a virtual bronchoscopy guidance hardware/software package, and a limited-performance first-generation VR system based on GE's Advantage Windows (AW) workstation. A second wave of products will draw on more powerful computers and more sophisticated software from this project for both the applications above and new applications. Full software from this project will be commercially available by 2000. Clinical trials of VE for FDA approval are also planned. The team is developing a 3-D abdominal atlas, has performed automatic segmentation using an expectation/maximization segmenter and has designed software for processing streaming images.*

Volatile Organic Compound (VOC) Sensors, Communications, Processing and Display 5164

Raytheon (formerly, Hughes Aircraft Co.)

OBJECTIVE AND GENERAL STATUS: Detecting volatile organic compounds (VOCs) continuously, reliably and with high sensitivity with inexpensive, portable, low-power distributed sensors is a demanding challenge, whether for military uses (e.g., detecting chemical warfare agents (CWA) and explosives) or civilian uses like monitoring powerplant and industrial emissions regulated by the 1990 Clean Air Act Amendments (CAAA). The military services also face environmental-monitoring needs because they operate industrial facilities like paint-spraying booths whose VOC emissions are covered by federal, state and local laws. This project targeted VOC monitors for Marine Corps spray-painting booths. These employ a $30,000 Fourier-transform infrared (FTIR) spectrometer and an air pollution control system (APCS), fitted with flame-ionization detectors (FIDs) on its inlet and outlet, that destroys VOCs in the booth exhaust. The TRP sensor targeted the FTIR but can replace the FIDs as well. The team planned an integrated system combining low-cost sensors with signal handling, telemetry, graphical user interfaces and display, and remote or centralized control.

MILITARY AND COMMERCIAL INTENT AND STATUS: *This project met its technical and cost goals, despite an 18-month congressionally driven delay. The simple, lightweight TRP sensors are rugged; draw very low power; have no moving parts or ionization sources (flames, sparks, hot filaments, high voltage); detect VOCs to one part-per-million (1.0 ppm) and CWAs to 0.1 ppm and distinguish among them; can be networked by cable or wireless; and can be built as conformal (wrap-around) sensors. Through miniaturization and embedded digital microprocessors, their technology can be extended to compact, rugged artillery-fired CWA sensors whose parts can also go into durable industrial sensors.*

Despite successful tests on the Marine Corps' paint booths, Hughes chose not to commercialize the sensor, given Hughes' mostly military product line. Hughes was then bought by Raytheon, which is undecided about the TRP sensor but won an unfunded DARPA award for a one-cubic-inch "unattended ground sensor" (UGS) derivative. This radio-equipped CWA sensor can be miniaturized to a 0.1 inch cube (or smaller), with anticipated production costs below $1. Raytheon is marketing it for artillery delivery from 5-inch Navy guns. The U.S. Special Operations Command (SOCOM) seeks a hand-emplaced variant, but has no money to buy it. Raytheon is developing another variant for a classified project.

Wearable Computer Systems with Transparent, Headmounted Displays For Manufacturing, Maintenance and Training Applications 1033

Boeing Computer Services

BACKGROUND: Boeing Computer Services, Honeywell Military Avionics Division, Virtual Vision, Inc., and Carnegie Mellon University is developing a portable, head-mounted display (HMD) with a position sensing system. One version of the system superimposes images directly on the surface of objects, while a second version projects text and images onto the operator's protective face shield. This enables "hands-free" presentation of information for manufacturing, assembly, maintenance, or training operations to improve productivity and accuracy. Boeing intends to incorporate this technology directly into its aircraft production. This effort will combine commercial virtual reality technology with DoD-developed components. Active matrix 1.5" x 1" LCD and ElectroLuminesence (EL) displays are being developed with 1280 X 1024 pixels. At this time, Japan owns about 95% of the market for displays, but they are not looking at single crystal silicon - U.S. is world leader in this technology.

OBJECTIVE AND GENERAL STATUS: To develop a portable, head-mounted display with a position sensing system with two advanced transparent HMDs that provide significant improvements in manufacturing and repairing of DoD systems. This will result in high resolution (i.e., accurate) displays which change on command. Through voice commands, a technician will be able to display schematics, drawings and even a full color picture related to the specific repair or maintenance job. Several advantages accrue from this technology. The need for the cumbersome paper equivalents is eliminated, permitting the worker to work "hands free" in confined spaces such as submarines or aircraft fuselages. Also, it ensures that the correct and most up-to-date information is always available. On or near the battlefield, technicians will have electronic access to the latest information on all of the varied weapon systems, permitting much more efficient and flexible operations.

MILITARY INTENT AND STATUS: *Light-weight, HMD goggles are working now and are available for demo. These 11 ounce goggles are compared to the 9 pound helmet displays they replace. In general, there is a need throughout the military, in combat as well as logistics domains, for rapid, convenient access to large quantities of information. The project has demonstrated several logistics-related applications. Other companies, such as Motorola, in their MARSS DoD contract, are demonstrating the combat potential of wearable computers. Head-mounted, see-through displays, originally developed for military helicopter pilots, have found employment in the commercial manufacturing world that will return benefits to the military. In its most advanced form, the wearable computer superimposes instructions, hole or placement locations, or correct orientations directly on a workpiece. It also greatly facilitates the entry of data into the computer, while performing the job. In a demonstration at McClellan Air Force*

Base, KC-135 skin inspection times were cut in half. The logistics systems engineers at this facility have ordered additional prototypes to be integrated into their operation.

The consortium has designed, built and tested three generations of prototype Augmented Reality Systems. They developed three different wearable PC systems, including a design from Carnegie Mellon University as well as the commercial vendors Flexible PC and Telxon. The 1996 ARS prototype used an innovative, untethered "videometric" head tracker. For the wearable PC or Multimedia System (MMS), they demonstrated the use of speech input and a variety of manually-controlled input devices for the user to control the wearable system. They also demonstrated the integration of a video camera mounted on the head-mounted display, for seamlessly transmitting the scene in front of the wearable computer user to a remote colleague.

COMMERCIAL INTENT AND STATUS: Eyewear that "projects" markings on a workpiece that are exactly positioned and invariant to head position will allow workers the ability to manufacture complex parts more efficiently and with more accuracy. Further, the rapid ability to adapt the display to the specific piece allows a flexible manufacturing environment which does not penalize lower volume, few of a kind, production runs. *Boeing has demonstrated the use of this technology in its 757 maintenance operations, and is conducting a pilot project to assess the systems efficacy in aircraft wire bundle assembly.*

There are now two companies, Virtual Vision of Redmond, WA (a TRP project team member) and TriSen, Inc. of Minneapolis, MN, (who developed the videometric tracker under subcontract from Honeywell) who are presently developing next-generation Augmented Reality Systems to be evaluated by Boeing in a large-scale pilot project this May and June. This pilot project is intended to provide the cost-benefit analysis data to support a decision by Boeing on whether or not to deploy the ARS for wire bundle assembly. This deployment, if approved, would entail the procurement of several hundred AR systems.

There are now several companies around the U.S., including Phoenix Group, Flexible PC, Rockwell Collins, and Xybernaut, which are manufacturing and selling wearable PCs to military and commercial customers. Head-mounted displays for these systems are provided by other U.S. companies, including Virtual Vision, Virtual I/O, and Kopin.