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SCIENTIFIC, ENGINEERING, AND TECHNICAL ASSISTANCE TO ARPA — CLOSE COMBAT TECHNOLOGY

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SCIENTIFIC, ENGINEERING, AND TECHNICAL ASSISTANCE TO DARPA'S LAND SYSTEMS OFFICE—CLOSE COMBAT TECHNOLOGY

This effort represents System Planning Corporation's final deliverable under contract MDA972-90-C-0044 in accordance with Data Item 0004AC. This Scientific, Engineering, and Technical Assistance (SETA) effort provided direct support to DARPA's Land Systems Office (LSO) in the broad area of close combat technology. The scope of SETA activities included a wide range of armor/antiarmor (A^3) efforts, including chemical-energy (CE) and kinetic-energy (KE) weapons; ceramic, reactive and laminate armors; active protection techniques; electromagnetic and electrothermal propulsion; missile and rocket systems; direct and indirect fire control technologies; hypersonic munitions; dispensing technologies; mine/counter-mine systems; vehicle propulsion and fire control; and simulation systems. We worked closely with LSO supporting the monitoring and management of both national and international programs and established many working relationships with both government and industry participants.

SPC provided program management assistance in preparing and evaluating program plans, work breakdown structures (WBSs), milestone schedules and costs, test plans, briefing materials, and other related management documents. This included the preparation, submission, and review of competitive announcements; monitoring and evaluation of program plans and schedules in organized program reviews; tracking of technical and fiscal milestones; and providing required monthly and quarterly reports.

SPC supported LSO's close combat technology efforts by providing multimedia presentation aids and writing and typing of administrative correspondence and memoranda, and preparing technical reports and documentation. SPC coordinated conferences, meetings, and provided technical library support, including the handling, storage, and retrieval of classified materials up to and including Top Secret/Special Compartmented Information. SPC has at all times maintained rapid response to the program requirements. The following represents a summary of the specific tasks performed by SPC under this contract:

A. RED DESIGN BUREAU SUPPORT

In Phases I and II of the Red Design Bureau (RDB) task, SPC supported investigations on future Soviet capabilities in tank armor, KE penetrators, and CE warheads. This highly successful effort performed for LSO by Battelle furthered U.S. understanding of the threat and provided credible hardware for use in testing of developmental munitions and armors. These robust targets and munitions were primarily used by the blue A^3 Program contractors.

Phase III presented new challenges. Given the demise of the Soviet Union, the RDB was faced with a potential worldwide threat due to proliferation. The Phase III objective was to project, design, develop, simulate, fabricate, test, and evaluate the best possible realistic representations of threat armor protection systems, CE munitions, KE penetrators, and active protection systems (APSs) expected to be deployed in the world in the 2003 to 2011 time frame. The RDB goal is to complete intelligence and R&D community validation of A^3 surrogate designs as threat range targets and surrogate munitions. Phase III will also define the parameters of the surrogate threat A^3 system characteristics required by simulations and databases such as Simulation Network Development (SIMNET-D), Battlefield Distributed Simulation Development (BDS-D), and the National Armor Data Repository (NADR). Phase III will be completed in 1994.

The SPC Red Design Bureau task had two objectives. The first objective was programmatic and administrative: to support the LSO program manager in the areas of program planning, procurement, technical evaluation, management of research contracts, preparation of threat technology surveys, data analysis, concept definition, test planning, military operational analysis, and administration. The second objective was to define the radar sensor of a foreign APS in sufficient detail to facilitate countermeasure development and computer modeling. To accomplish these objectives, SPC:

- Conducted kickoff meetings and technical quarterly program reviews to evaluate the RDB contractor's (Battelle's) technical and programmatic performance for the RDB, Robin Hood, Lone Ranger, and Zane Gray programs, and provided technical assessment to the program manager following the reviews.

- Developed the RDB Phase III program plan and supported Phase III procurement. To develop the program plan, SPC conducted a workshop and surveyed the user, Intelligence, and R&D communities to determine priority threat technologies and conflict regions of interest for the Phase III focus. The Phase III procurement activities included preparation of the *Commerce Business Daily* announcement (BAA 91-07) and Source Selection Plan, presentation of briefings to the evaluation panel, hosting the Briefing to Industry, providing security control for the classified proposals and meetings, and preparing the final selection documents and Statement of Work for contract award. Battelle was selected to continue with the Phase III program.

- R[illegible]ed RDB sections of the Joint A^3 Program Security Classification Guide (C[illegible]-[illegible]07) to allow the United Kingdom access to the RBD Phase II targets.

- Prepared JPO exhibit for the Marine Corps Research, Development, and Acquisition Command (MCRADC) Science and Technology Fair.

- Reviewed the RDB Phase II, Lone Ranger, Robin Hood, and Zane Gray final reports and provided technical direction.

- Conducted a study to design an APS radar to meet the RDB. SPC conducted research, interviews, designed the radar system and antenna, and developed a final report. SPC made numerous presentations to the Intelligence Community, and the results from these efforts directly supported the Army Material Systems Analysis Activity (AMSAA) Threat APS working group.

B. PROGRAM ADMINISTRATIVE SUPPORT

1. Director/Program Administrative Support

SPC provided support to LSO, including the following:

- Administrative support to the Director (LSO) from September 1991 through January 1993.
- Preparation of briefings for program reviews.
- Travel to the Department of Energy–Albuquerque (DOE-ALOO) and to Los Alamos National Laboratory to assist in reconciliation and transfer of the CE contracts from DOE-ALOO to USA Missile Command, Huntsville, Alabama.
- Supported the Assistant Director, Program Management, in preparing Army quad charts and tracking contract expenditures for LSO contracts.
- Organized and hosted several conferences for LSO, including Senior Advisory Group meetings, program reviews, and BAA and proposal reviews.
- Organized, coordinated, and attended the A^3 Review Conference in Santa Fe, New Mexico, September 15–16.

2. Resource Information Management System (RIMS) Support

In support of RIMS, an information management system that was established under the former Tactical Technology Office and eventually transferred to LSO, SPC tested the RIMS program and reviewed previous input. RIMS is the prototype of the current DARPA management information system. SPC determined that the RIMS was not flexible enough for LSO needs and recommended that LSO use the DARPA management information systems and/or DTIC.

3. Balanced Technology Initiative (BTI) Support

SPC developed budget tracking mechanisms for the BTI programs (placed in DARPA's charge in the beginning of FY93), prepared all DPRs and AOs for all service-directed BTI programs, established files for the BTI programs, and tracked all funding documents associated with the program.

C. ADVANCED SURVIVABILITY SYSTEM SUPPORT

SPC supported one of the most diverse and active areas under the management of LSO—advanced survivability systems. During most of the SETA contract period, no less than seven major program activities were in concurrent operation. These included three Phase II Armor Protection programs with Alliant TechSystems, DuPont, and General Dynamics; two international NUNN program initiatives with Food Machinery Company (FMC) and Kaman Science; a major light armor effort with Foster-Miller; and a classified program.

The Phase II efforts addressed the development, fabrication, and testing of light, medium, and heavy armors. SPC, under DARPA direction, maintained close liaison with the government user, laboratories, and industry concerning product technology that coupled advanced materials and unique defeat mechanisms with identified user needs. We participated in the development of program plans, security guidelines, test planning, and program reviews and assessments. We also worked closely with TACOM, ARL, CSTA, the Navy and Marine Corps, and the national laboratories to help sustain user-in-the-loop awareness and facilitate the generation of unbiased and uniform data.

The international programs coupled U.S. industry with foreign partners to address research in areas of common interest. FMC, with their German partner IBD, developed advanced armor protection solutions using advanced materials and novel defeat mechanisms to address a wide variety of threats. Kaman Science, with their industrial partner, SNPE of France, addressed the problem of responsive armors that could provide effective CE threat solutions while minimizing collateral damage effects associated with reactive armors. The potential of defeating KE threats using this technology was also examined; the results, however, are classified and cannot be addressed here. SPC played a significant role in both these programs, including the drafting of most program initiation documentation, the development of international program security guides, participation in many of the program reviews, and assessment of program results.

Foster-Miller's Light Armor Systems Technique (LAST) armor offered a unique opportunity to apply DARPA technology to Operation Desert Storm. This unique hook-and-loop attachment method allowed the fielding of 75 armor appliqué kits for the USMC LAV in an amazing 3-month time period. The first high-rate-production demonstration of armor ceramics (Coors and Lanxide) and the first truly modular combat vehicle armor resulted from the Gulf War requirements. SPC provided program planning and coordination support, drafted the operational test plan, and directly participated in the integration of the kits on the LAV. The Phase II LAST program also examined a wide range of threat scenarios spanning ultralight to medium size vehicle applications.

Other SPC LAST-related efforts included the fabrication and demonstration of near-net shape composite technology for hatches (Lanxide), the selection and fabrication of a weapon protection system for the Line-of-Sight Forward/Heavy (Alliant TechSystems), the design of an armor enclosure for the M9 ACE microclimatic conditioner, enhanced protection options for the HMMWV, and demonstrations involving potential M1 upgrades. SPC also supported and coordinated several BAAs leading to contract awards in structural armors, transparent armors, and electromagnetic armor solutions.

D. ARMORED COMBAT VEHICLE TECHNOLOGY SUPPORT

The Armored Combat Vehicle Technologies Program, also known as the A^3 Technology Base Research Program (or Tech Base), was begun in early 1991 in response to a recommendation made at a Senior Advisory Group Meeting. When the subtask was started, its stated purpose was to allow the U.S. to catch up to the Soviet Union in A^3 capabilities and to develop a commercial capability to solve complex technical problems relevant to the A^3 community. As events progressed, goals evolved that led to A^3 technology enhancements through research into the underlying sciences.

The Tech Base program comprised a number of different areas, including materials characterization, development and dissemination of improved analytical codes, and research into advanced materials, novel computing techniques, and penetration mechanics. The Tech Base program was broken up into three main areas: computational mechanics, materials modeling, and materials development. The computational mechanics section funded tasks for providing hydrocodes to users, making improvements to existing hydrocodes, and reducing hydrocode run times. The materials modeling section funded experiments for increasing our understanding of the response of materials under high strain rates or under confinement, studies of ceramics and their damage evolution, and post-shot failure analysis studies utilizing PIXY (Los Alamos X-ray facility) data. Materials development work included microwave sintering techniques for ceramics and investigations into the use of Carbon 60 as an armor material. Overall, there were approximately 25 separate tasks per year for the Tech Base program.

General tasks performed by SPC included the generation of funding documents such as DARPA Orders and DARPA Procurement Requests; spreadsheet and database development; technical report generation; viewgraph development; and administrative, financial, and program management support.

SPC's specific accomplishments included an analysis of the costs associated with contractors utilizing Cray GFE computer time and an evaluation of the various options available to the Tech Base program. Considerable time was spent resolving the differences between the various hydrocode distribution agreements at Sandia and Los Alamos National Laboratories. SPC also developed a number of technical charts for use at meetings and conferences and prepared a questionnaire and performance criteria to determine the level of user satisfaction with various DARPA-supported hydrocodes so that downselection to one code could be performed. This downselection was overcome by events before completion of the selection. SPC also assisted with the development of a plan to form a consortium to develop an Integrated Armor Development System.

E. ADVANCED CE WARHEAD R&D PROGRAM SUPPORT

The technical and administrative task objectives for the Advanced CE Warhead R&D program were fourfold:

- Provide scientific and engineering assessments of warhead explosive and liner materials and the impact of these materials on increased warhead performance.

- Assess warhead designs with respect to weapon system integration and target armor protection parameters to ensure that performance of developmental warheads is compatible with antiarmor system requirements.

- Review program structure with respect to the technologies under consideration, their expected payoff, and contractor performance in developing these technologies to ensure a high degree of funding leverage in the accomplishment of the program objectives.

- Provide administrative support to the operation of the program, to include monitoring and reviewing contractor research, management of government action items, and preparation of program technical review packages.

During this program, eight contractors were tasked by DARPA to develop direct- and top-attack tandem and EFP warheads for existing and follow-on missile systems; advanced liner materials for greater deep penetration performance; and novel warhead configurations for enhanced lethality against modern and future armor arrays. SPC supported the procurement and programmatic process by participating in contract technical and cost evaluations, providing feedback to the PM on matters concerning negotiations with contractor technical and financial personnel; evaluating proposed and deliverable technologies through the development of analytical tools, models, and scientific research; planning and monitoring test and evaluation of hardware deliverables; and performing the day-to-day management of program administrative functions. This SPC support continued throughout the Phase III procurement process and ultimately to the physical transition of the program to the U.S. Army Missile Command in December 1992.

An interesting outcome in the Phase III program formulation was the investment in a novel unitary warhead concept for the defeat of reactive armor appliqués in conjunction with the base armor array. In a sense, the concept is to develop a unitary tandem warhead, which is not a new idea since contractors have proposed dual-pulsed warheads or prompt-tandem unitary liner designs for the defeat of reactive armor over base armor. Few warhead concepts, however, have shown as much potential to meet missile kinematics, warhead modeling, and liner technology requirements. In addition, a systems-oriented application exists in the current antiarmor weapons inventory.

SPC's contribution to the selection of this contractor-proposed research in the Phase III program stems from extensive consultation with the previous CE program manager, Dr. Fred Grace. During Dr. Grace's tenure as program manager, discussions were informally held on the future of warheads and missile technologies, and what aspects of warhead research should be emphasized. A consensus was reached that conventional tandem warheads were becoming over-evolved, expensive, and complicated to package into missiles and that something revolutionary would eventually be required in antiarmor missile system such as a simplified unitary tandem warhead. At the time, however, we could not conceptualize the warhead. Then during the Phase III procurement, 3 years later, one contractor (Hunting Engineering) proposed a warhead concept with an antiarmor application that met the SPC/DARPA desired characteristics. SPC brought the concept to the attention of Dr. Terry Phillips, who presented it to the evaluation team as a whole, and the proposal was received favorably. This is just one example of how SPC's knowledge of warhead R&D has proved invaluable to DARPA.

F. ARMOR REPOSITORY SUPPORT

To ensure that data relating to the NUNN Armor Program would be compatible with the newly established National Armor Data Repository (NADR) (see Task 7, NADR Institutionalization), SPC developed a database and master dictionary to input consequential NUNN Program data into a common computerized format compatible for output and inclusion to the NADR. Data from multiple sources (e.g., Kaman Science and SNPE) were in a variety of formats, including database, spreadsheet, and noncomputerized form. These data were made available [illegible] format, complete with field descriptions and master data dictionary form. In addi[illegible] several adjustments to the AADS/NADR interface software to accommodate changes [illegible] data structure of the NADR-ready format. These tools were used in the transfer of NUNN program data into a NADR-ready format. However, these data were never actually transferred as a result of specific direction given by the LSO program manager.

G. NADR INSTITUTIONALIZATION SUPPORT

SPC provided technical support to NADR. The NADR concept was originally advanced by the U.S. Army Tank and Automotive Command (TACOM), for which SPC developed the Army Armor Database System (AADS). AADS included A^3 data and tools that could be accessed via a personal computer platform. AADS users from both the private and government sectors met annually to discuss system use and potential data sources. Several years later, the scope of this group was expanded to investigate a greater diversity of data sources from all branches of the armed services. NADR was established to provide a central repository for A^3 data generated in a variety of formats from numerous government and private sector sources. An organizational structure was created to provide a mechanism for data review and validation, as well as the continued advancement of the NADR concept throughout government and industry. The Executive Committee, established to manage the direction of NADR, included representatives from the U.S. Air Force Chicken Little Program Office, U.S. Army TACOM, DARPA, Joint Technical Coordinating Group for Munitions Effectiveness (JTCG-ME), and Office of the Secretary of Defense, Live Fire Testing.

In 1988, NADR was proposed to the JTCG-ME as a continuing effort that would be supported by them for 3 to 4 years and ultimately be turned over to the SURVIAC contractor for continued maintenance. System Planning Corporation, as the designer of the widely accepted AADS, was tasked to provide technical support to NADR in areas of database design and technology and to represent the interests of AADS users in the formation of the repository. Additionally, SPC would supervise the transfer of current AADS data holdings to NADR, which is maintained by the U.S. Air Force, Chicken Little Program Office, at Eglin, AFB. To support the goals of NADR, System Planning Corporation designed a data interface for the AADS that facilitated the maintenance, search, and retrieval of NADR datasets on a PC platform. Under this task, SPC was responsible for maintaining and, when necessary, adjusting this software in support of NADR data and design goals.

Technical problems that were encountered and SPC solutions to them during NADR development are noted below:

- **Integration of diverse data.** The type of A^3 data collected during testing is highly dependent upon the testing strategy and method employed. A primary NADR goal was to preserve all data recorded during any particular test program. Therefore, it was necessary to devise a flexible structure for data storage that allowed for the presence of a variable number of fields among different data files. The file format also had to be widely recognized and easily convertible to other computer-readable methods of data storage. Additionally, where possible, it was desirable to impose some commonalty on the data to facilitate search and retrieval using automated tools.

  Solution: SPC proposed the use of generic, ASCII-formatted "flat files." This format imposed no restrictions on the type or number of data fields that could be maintained by any particular data set and was easily readable by a variety of computer platforms. SPC provided technical support in the areas of database design and computer interface for this task. In order to codify the file structure required for the inclusion of data files in NADR and facilitate access to these files using AADS, SPC produced a Master Data Dictionary Specification.

- **Documentation of the data.** Inevitably, key information (e.g., units of measure, test conditions, general comments, diagrams, photographs, narrative) describing the data was unavailable in digitized form. Without this information, the actual test results were difficult or impossible to analyze. Therefore, it was necessary to review data submitted for inclusion in the NADR and determine if additional supporting documentation was required.

  Solution: SPC proposed to expand the available data fields to accommodate this additional information.

- **Data provided in various computer and hard copy formats.** To obtain data from the widest spectrum of sources, it was necessary to accept data in both digitized and hard-copy report formats. Data supplied in digital formats could be submitted in either DOS or Macintosh formats and be downloaded from numerous database, spreadsheet, and word processing commercial packages.

  Solution: SPC developed several data conversion tools that could be used to translate data from a number of popular PC packages into NADR-ready format.

- **Transfer of the AADS data.** AADS comprised a large collection of armor, material, munitions, and ballistic data maintained by a relational database management system with tools and data links to make the data meaningful. To provide the AADS data set to NADR, data had to be downloaded in a NADR-ready format and sufficient documentation supplied to interpret the data.

  Solution: SPC-developed data translation tools were used to download the AADS data into a NADR-ready format. A NADR-style data dictionary was provided for each of the six databases maintained by the AADS software. In addition, documentation, including a glossary of all fields and the standard data input forms, was supplied. SPC also provided a description of the coding scheme employed by the AADS software.

- **Maintenance of NADR data tools.** To take advantage of NADR data, it was necessary to develop computer tools capable of search and retrieval as well as graphical output and report generation. Since NADR was initially maintained on a VAX minicomputer, tools for this environment were provided by a DARPA contractor, TASC, in Eglin, Florida. AADS and other users required similar tools for a PC environment.

  Solution: SPC developed, maintained, and updated NADR data tools for the IBM-compatible PC. Some of these tools represented a significant SPC software development effort. These tools established an important link between PC users and NADR by allowing the user to upload a data set received from the NADR on floppy disk to a central repository maintained on a removable hard disk cartridge. The data can be searched, examined, printed, or plotted. Additionally, the data can be reformatted into several popular commercial formats, including LOTUS, dabs, FOCUS, and Lotus Symphony for use in other applications. Conversely, the user may upload a data file in any of these commercial packages and download it via floppy into a NADR-ready format file for submission to the data repository. An AADS was installed at the Chicken Little Program Office in Eglin so that the AADS data translation capabilities could provide direct support to NADR. SPC has made several adjustments to the AADS/NADR interface software to accommodate changes in the data structure of the NADR-ready format. In addition, these tools were used in the transfer of NUNN program data into a NADR-ready format. SPC-developed tools for translation of NADR data in various formats, report generation, and pen-plotting capabilities. The PC tools were expected to continue to evolve in response to changes in NADR structure and goals. These tools could also be used to convert data submitted for inclusion in NADR from various data formats and structures to NADR-ready data files.

In addition to the above, SPC representatives attended two meetings of the NADR working group at the Eglin offices of TASC. They provided technical guidance and support in developing the data and organizational specifications integral to the NADR system. In addition, SPC continued to develop a data translation scheme and software for preparing data created in a PC environment for inclusion in the NADR. A complete AADS was installed at Eglin Air Force Base to make the AADS/NADR interface translation capabilities available to NADR.

H. BATTLEFIELD MANAGEMENT SUPPORT

The purpose of the Battlefield Management Program was to develop and demonstrate a battlefield management system for future land combat vehicles that would provide complete situational awareness and target servicing to enhance combat effectiveness. The program integrated state-of-the-art technologies for combat identification, remote target acquisition and firing, information management, low-probability-of-intercept (LPI) voice and data communications, position determination, navigation, multifunctional displays, multispectral sensors, mission planning, and electronic warfare. This program was a technology development and proof-of-principle effort out of which successful concepts would be transitioned to a complete system to be demonstrated in support of the Advanced Land Combat Science and Technology thrust.

This program was initiated with the procurement for the Advanced Land Combat Vehicle Technologies (BAA 92-04). This procurement was soliciting very high-payoff, high-risk ideas for technologies applicable to an advanced land combat vehicle that is highly deployable, transportable, producible, sustainable, and able to support U.S. expeditionary forces in contingency operations anywhere in the world. The technology applications focused on survivability, lethality, mobility, communication, and support; the technologies were to have a maturity level capable of integration into a vehicle with initial operation in year 2005. SPC provided technical comments to the program manager on the proposals submitted, developed a database to track the procurement, assisted the program manager in developing selection documentation and statements of work, and participated in the program kickoff meeting and technical reviews. The Battlefield Management Program contracts were awarded to Georgia Tech Research Institute for an NLOS sensor; to Telephonics for an in-the-ear microphone and earphone, fast-hopping digital synthesizer processor, and high acoustic voice recognition system; to Hughes for an integrated vetronics concept; and to Raytheon for an integrated FLIR, radar, and LADAR sensor concept.

In a related effort, SPC assembled a battlefield management team, including General Research Corporation and Maritime Applied Physics Corporation, to develop a program strategy and plan for a feasibility demonstration of an integrated combat vehicle crew station featuring advanced display and information gathering and dissemination capabilities. The elements of this effort consisted of a combination of technology surveys, breadboard demonstrations, and detailed analyses of operator needs and capabilities to help define a prototype advanced system. SPC prepared and presented briefings to DARPA management under the direction of LSO and wrote a report documenting this effort.

I. BATTLEFIELD IDENTIFICATION FRIEND OR FOE (BIFF) INITIATIVE SETA SUPPORT

SPC provided support to the program manager, BIFF Initiative, in the areas of planning, procurement, and administrative support; military operations and data analyses; theoretical development; and technology transfer. The objective of the BIFF program is to develop and demonstrate a family of interoperable, antifratricide systems suitable for use on future ground and airborne weapons platforms as well as support vehicles. The program will address ground-to-ground direct fire and indirect fire engagements as well as air to ground and ship-to-ground engagements in the 21st century.

The long range and high lethality of modern weapons make it imperative that the United States be able to discriminate friends from foes at extended distances on the modern battlefield. This allows U.S. weapons to be used at their maximum effective ranges, where the troops that operate them are least exposed to hostile enemy fire. BIFF capability has recently received more attention due to increasing engagement ranges. However, signals that friendly units may emit in order to warn allies not to fire at them may also be exploited by enemy forces and used to target the emitters. Encryption schemes to prevent this enemy exploitation may be so complex and expensive that the IFF system is not proliferable to the large number of ground and air vehicles required to achieve comprehensive coverage. DARPA has been appointed executive agent by Congress to lead advanced BIFF technology efforts.

DARPA's Land Systems Office has decided on a two-pronged approach in its executive agent role. One leverages existing technology to fashion a near-term solution that can be fielded relatively quickly. The other is to develop and integrate promising emerging technologies for a more robust future system. LSO is currently sponsoring tests of advanced technology systems selected by the U.S. Army for evaluation. Several of these involve the use of the Global Positioning System satellite network to share positional data among platforms for increased situational awareness; others use laser interrogation and directional electromagnetic responses. LSO also is evaluating proposals for still more advanced identification systems. These approaches will be evaluated through simulation on a synthetic battlefield to help determine their potential feasibility and military utility.

SPC organized and hosted several BIFF initiative conferences, including the Ground Combat Identification Seminar, Hazeltine Corporation Contract Kickoff Meeting, and MIT/DARPA Modeling and Simulation Workshop on Combat Identification. SPC also organized and hosted BIFF program reviews, BAA evaluation, and proposal reviews.

J. SMALL, LOW-COST INTERCEPTOR DEVICE (SLID), MINE, AND COUNTERMINE PROGRAM SUPPORT

The primary objective of SPC's effort is to provide technical, analytical and program management support to the developing Small, Low-Cost Interceptor Device (SLID) and the Mine/Countermine Programs. The mine program consists of the Anti-Helicopter Mine (AHM) and Minefield Command & Control (C^2) programs; the Countermine program is divided into

Handheld, Ground-Vehicle, and Airborne subprogram efforts. SPC has been supporting all of these programs since their inception and has provided technology assessments, test plan development assistance and implementation, military utility assessments, and concept evaluations.

1. Small, Low-Cost Interceptor Device

The technical objective of the SLID program is to develop (demonstrate and test) hit-to-kill devices capable of highly agile lateral maneuvers. These devices can be used in a variety of applications to provide ground/air vehicle close-in self-protection against incoming missiles and projectiles and to serve as a barrier against low-flying air vehicles. The current application is for ground vehicle self-defense.

Currently the SLID program is finishing the concept definition phase with six contractor teams. Based on contractor analytical results, it appears feasible that a SLID projectile can be successfully deployed for antiarmor missiles and projectiles. At this point in time, tradeoff studies are being conducted to quantify system error budgets and identify critical risk technologies and timeline drivers. SPC has hosted all program reviews, assembled and distributed technical minutes, and provided technical assessments/evaluations on each contractor system.

SPC assisted in writing the Phase I/II System Development SOW currently released. Because of the immaturity of the program, technology transfer issues have not fully been defined. Members of the Armor, Infantry, and Air Defense Schools are attendees at the meetings and support SLID development. TACOM, MICOM, AMSAA, and ARDEC support the program both technically and administratively.

2. Mine/Countermine Programs

The goal of the Countermine program, which began in 1987 as a result of a Defense Science Board Summer Study, was to combine sensor technologies (radar, metal detection, nuclear, IR, chemical) to get the best sensor system platform (high P_D and low P_{FA}) to find all mine types (e.g., plastic, metal, wood) in all environmental conditions (e.g., depth, soil conditions) while significantly enhancing the rate of mine detection and marking (5-10 mph). The program has evolved into three Countermine subprograms: Handheld, Ground Vehicle, and Airborne.

The Minefield C^2 and AHM programs are intended to add two more dimensions to mine warfare. First, to provide a two-way communications capability for a minefield; and, secondly, to develop a mine that can deny nap-of-the-earth flight to threat helicopters.

The Minefield C^2 program successfully demonstrated two-way communications (i.e., on/off, arm/disarm, information transfer, and networking). SPC performed an analytical assessment of the jamming robustness of each of the five contractor systems. In addition, SPC performed laboratory and field jamming tests of several of the contractor systems. This was accomplished with SYN-JAM, an SPC patented product. SPC also participated in the development of the brassboard test plan and execution. Administrative duties, such as graphics support, conference/meeting planning, program coordination among various contractor and DoD agencies, were also performed by SPC. The Minefield C^2 program has been successfully transferred to the ARDEC program manager for Wide Area Mines.

The AHM program is currently in the F^3 (form, fit, function) phase. F^3 means the mine looks, feels and acts like the real AHM; however, the contractor does not need to provide all the reliability, availability, maintainability (RAM) and integrated logistics support (ILS) documentation. These elements are to be developed by the user agency when the program is transferred. SPC has assisted in the creation of the brassboard and prototype, test planning, operational/employment studies, AHM simulation and utility modeling, and administrative support. From SPC's modeling and simulation efforts, it was concluded that an AHM equipped with two-way communications can significantly enhance current air defense assets. The AHM program has had significant support from several user agencies (USAES, USAADS, USAAS). The USAES has written and approved a mission needs statement (MNS) and has conducted system-level force-on-force simulations using CASTFOREM. The program is intended to be transferred to the Army (PM-Mines/ARDEC) in FY94.

The Handheld Mine Detection program demonstrated/tested four contractor systems:

- **Thermedics/Coleman.** The integrated Thermedics, Inc./Coleman Research system combines electromagnetic anomaly detection with detection of explosives. A wide-band, stepped-frequency, ground-penetrating radar (GPR) serves as the anomaly detector and a chemiluminescence-based chemical analysis system verifies the existence of explosives. The GPR has the ability to locate metallic and non-metallic objects on or below the surface of the earth. It specifically combines wide-band, stepped-frequency operation with dual, circularly polarized, cavity-backed spiral antennas. Radar data are collected, processed, and synthesized to generate a target image on an integrated display to the operator.

- **SAIC.** The SAIC detector is a neutron thermalization system that uses a fast neutron source (small ^{252}Cf source) and a thermal neutron detector (^3He proportional gas counter). Hydrogen, present in explosives and plastic mine cases, scatters and thermalizes fast neutrons more effectively than other elements.

Consequently, as the source-detector combination is scanned over the ground, the presence of a buried mine is detected as an increase in the detector thermal neutron counting rate. Feedback to the operator is provided both audibly and visually.

- **General Dynamics.** The General Dynamics system combines two electromagnetic sensors for locating land mines. The first sensor consists of nine patch antennas arranged for six-frequency operation in a balanced-bridge configuration with a central transmitting element and two outboard receiving elements. Multifrequency operation is accomplished by stacking three patch antennas to form each element. Feedback to the operator is provided by an audible tone and a visual display. The second sensor is a single-frequency, multielement microstrip antenna array that is coplanar with and located behind the first sensor. An image of the target is formed by electronically scanning through each element (pixel) of the array. Results are depicted on a color LCD.

The test plan consisted of testing the systems in both a controlled environment (inside) and in uncontrolled environments (outside). Indoor test results indicate that detection rates are good for all systems. However, false alarm rates are too high, except for the SAIC system. Outdoor detection rates were significantly reduced and false alarm rates significantly increased. A confirmatory sensor is highly desirable for both GD and Coleman GPRs. SAIC system may prove useful in very dry soil (<5% moisture).

The Thermedics/Coleman's system was tested both inside and outside. Initially, the Coleman GPR was tested by itself in the September/October 1992 timeframe. The Thermedics chemical sensor was tested in March of 1993. The GPR proved most effective indoors in dry soil, and P_D & P_{FA} degradation occurred for wet soils and outside test conditions. It can be hypothesized that a significant improvement could be achieved if the GPR works in conjunction with the chemical sensor. The chemical system, though cumbersome to use, is very effective in detecting the presence of nitrogen.

The SAIC system demonstrated extremely low false alarm rates in dry sandy soil (as one would figure). This system was only tested indoors; it has minimal capability in soil containing above 5% moisture content.

The GD balanced-bridge GPR was not as effective as the Coleman GPR largely because of the data display. The display showed two-dimensional ground contours. However, the 40-element array allowed 40 points of data to construct the contours. This was not sufficient for the user to distinguish false (clutter objects) from mines. As a result, the false alarm rate is significantly higher than expected. The complete test results are documented in a BRDEC document entitled *DARPA Handheld Mine Detector Results: Field Test.*

3. Ground Vehicle Mine Detection (GVMD)

Two GVMD systems were developed in the DARPA program and three systems tested. These are summarized below.

- **Geo-Centers/SAIC, GPR and Nuclear Activation Techniques.** The Geo-Centers approach is a GPR using a specially designed antenna that focuses time-coordinated short pulses. The return pulses are combined in a neural-network synthesis to optimize target discrimination. The antenna design is a variant of a transverse electromagnetic (TEM) beam, and the waveform is compact in time, with a frequency of about 1 GHz. The SAIC system concept depends on irradiation of a swath using californium-252 and an electric accelerator as the neutron source, and detecting the 10.8-MeV gamma response of the nitrogen reaction in the mine explosive. The sensor is an array of sodium iodide (NaI) scintillators, and appropriate signal processing is proposed to discern the mine signature from the soil and clutter background. The combined system performance goals are standoff of 4-10 inches, scan width of 10 feet, advance rate of 6 mph, P_D of 95% of a mine buried 2-8 inches deep, and a false alarm rate of 1 per 500 yards.

- **Titan Corporation, Mine Detection Using Energetic Photons (MIDEP).** In this approach, a charged particle beam (13-15 MeV) impinges on a target to form 13-MeV gamma rays, which are used to induce a reaction from nitrogen in the mine explosive, resulting in an emission identifiable with the presence of explosive. The problem is to determine whether the system performance parameters needed to provide the required levels of detection probability and discrimination reliability can be achieved within operationally acceptable size, weight, mobility, power consumption, safety, and maintainability constraints. For the immediate challenge of determining technical feasibility (postponing tactical and logistical considerations), the critical issue is the tradeoff analysis for selection of photon energy and intensity levels, detection sensitivities, and signal processing algorithms that will yield the needed high detection probabilities and low false alarm rates (i.e., discrimination reliability) in realistic environments of soil, clutter, and potential countermeasures.

- **ELTA, Ground Penetrating Radar.** This Israeli firm, not sponsored by DARPA, participated in the test. The concept centered on a ground-penetrating radar. The vehicle mounted test results indicate that detection rates are marginal to poor. False alarm rates are high by greater than a factor of 10. With continued development, these radar systems could be used for mine clearance. As a side note, these systems have minimal capability against small (AP) mines.

4. Air Vehicle Mine Detection

Lawrence Livermore National Laboratory (LLNL) developed a Temperature-Evaluated Mine Position Survey (TEMPS). This approach appears to have promise for detection of shallow buried and surface mines, both metal and nonmetal. The technique depends on the effect of a mine on the diurnal and climatic heat flow between the mine and earth surface, and the consequent small temperature difference produced at that location on the surface. The resulting images are color enhanced to heighten contrast and aid the observer's discrimination. The analysis indicates that a temperature difference not less than 0.2°C is required for detection. The system is designed to discriminate these subtle differences from the emission signals (typically 1-2°C) from surface objects (rocks, metal) and irregularities. Further, the system design, intended for airborne applications, will include a three-axis platform compensation to provide location precision. The underlying technology application uses spectral, spatial, thermal, and temporal characteristics to locate, discriminate, and map the following:

- Small (0.2°C) surface temperature differences of vegetation, environmental effects, mines, and other objects.
- Thermal "footprints" from surface and buried mines that heat and cool at different rates from their surroundings.
- The signatures of areas with natural surface temperature variations of vegetation, environmental effects, and other objects.

The LLNL program is currently ongoing. Specific areas of research involve the signal processing algorithms necessary for discrimination of mines and minefields. The TEMPS work will be used to assist in the REMIDS Program selection board.

SPC's efforts in support of the Countermine programs consisted of participation in test plan development, organization and coordination of in-process reviews, and technical evaluations/assessments of contractor systems. The Countermine program has received limited funding and, as a result, SPC's supporting efforts were minimal.

The only Countermine program being transferred to the Army is the Handheld system. BRDEC will pick up complete funding of these systems. The ground vehicle systems were scheduled to be transferred in FY94, at which time, the system would be more mature and refined. However, since funding has been eliminated, it seems unlikely that the program will ever be transitioned from DARPA to the Army.

K. ELECTRIC/HYBRID/NATURAL GAS VEHICLE TECHNOLOGY AND INFRASTRUCTURE PROGRAM SUPPORT

SPC supports the development of electric, hybrid, and natural gas vehicles and their associated infrastructure. The purpose of this program is to explore vehicle, vehicle component, and infrastructure technologies to accelerate their introduction, enhance their performance, and enable the armed forces and commercial sector to achieve energy cost savings and comply with national environmental objectives. SPC's support of this effort includes the generation of program documentation; government/industry coordination activities such as the workshop held at SPC on December 15, 1992; the development of procurement documentation; and the identification and assessment of applicable technologies.

This effort supports technologies that are of critical interest to both the military and commercial markets. The exploration of energy storage devices will include advanced batteries, conformal high-capacity fuel tanks, and regenerative devices. Energy-generation devices include environmentally friendly fuel cells and natural gas turbines. Control and distribution devices include the exploration of multifuel devices to significantly reduce emissions without sacrificing vehicle performance. Other activities may include advanced motor/controller designs, sensors, engine conversions, and charging options that are critical to establishing a viable infrastructure; range extension devices employing flywheels or super capacitors; and processing technologies for advanced lightweight, high-strength materials.

The program involves cooperation among various agencies, including OSD, DOE, DOT, and EPA. Industry is actively involved in the technologies of interest due to the obvious commercial potential for low-emission and zero-emission vehicles. The technologies developed and/or refined from this program will be directly related to both the military vehicular community as well as the commercial sector.

L. ADVANCED CREW COMPARTMENT TECHNOLOGY INTEGRATION PROGRAM SUPPORT

This is a joint U.S./German research and analysis effort to identify technology opportunities to augment the performance of future armored vehicle crews. This effort was jointly sponsored by DARPA and the German Federal Ministry of Defense through General Research Corporation (GRC), under subcontract to SPC (U.S.) and IBP Pietzsch (Germany).

A report was prepared by GRC that included a Systems Requirements Analysis, Crew Tasking and Technology Analysis, and a Program Plan. This study was driven by factors of mutual interest to both the U.S. and Germany:

- Recent world changes that dictate that both U.S. and German armed forces be lighter, deployable, more capable, and more survivable in coalition warfare.

- The near-term availability of advanced technologies that will improve the man-machine interfaces and allow crew size reductions and subsequent vehicle weight reduction with enhanced fighting capability.

- State-of-the-art simulation capabilities that allow promising technologies for armored vehicles to be identified on computer testbeds and combat containers.

- Likelihood that an advanced crew compartment concept will be developed in time for technology transition to a light contingency vehicle (LCV).

Technology opportunities were identified and categorized in the area of sensors, communications, displays and interfaces, and data management and processing. Current, near-term, and far-term capabilities and projections were made and documented by GRC and IBP in the following:

- *Advanced Crew Compartment Technology Integration Program,* Final Technical Report, June 1, 1992, Chapter 1-3.

- *Advanced Crew Compartment Technology Integration Program,* Chapter 4, Program Plan.

M. HIGH-ENERGY-DENSITY MATERIAL (HEDM) PROGRAM SUPPORT

SPC support the 4-month HEDM effort (September 1990 - December 1990), which assessed the need for HEDM and developed the program plan for implementation of an ARPA HEDM program (i.e., strategy, PAD, cost estimate, schedule, BAA and source selection documents). The effort explored the feasibility of the military application of novel and innovative metastable HEDM and structures, focusing on those that appeared to offer potential increases of 35% or more relative to conventional high explosives or rocket propellants. Subsequently, the decision was made not to proceed with this program. This effort was conducted by an SPC subcontractor, Interferometrics Inc., under SPC subcontract SPC-INT-91-C-95. The final report for this effort, Interferometrics Report 90-073, contains the draft program plan.

N. ARMS CONTROL PROGRAM SUPPORT

General Research Corporation, an SPC subcontractor, provided arms control support in support of OSD. The purpose of this effort was to provide a plan that compiled the basic USD (A) guidance under which a broad-based RDT&E program could be pursued in support of onsite and aerial inspection for arms control. The plan was designed to assist all DoD R&D activities in determining how their particular RDT&E efforts and innovative ideas might satisfy the priority national needs of arms control. A final report, *Program Plan for Research, Development, Test and Evaluation for Arms Control Cooperative Inspection,* was published on 20 March 1992 under the authorship of the DoD Verification Technology Research and Development Working Group.

O. MISSION KILL (MK) PROGRAM SUPPORT

In response to interest expressed by the Commanding General, U.S. Army Training and Doctrine Command (TRADOC), the Army Secretariat and Staff, and the Director DARPA, an effort was initiated to investigate and develop technologies that could efficiently defeat or degrade armor vehicles while not requiring a ballistic perforation of the armor envelope. A Mission Kill (MK) program was established in 1989 with four major participants, a DARPA/Army/USMC Joint Program Office (JPO) and the Army Chemical Research Development and Engineering Command (CRDEC). Following release of a BAA, 3 proposals were selected for funding out of 60 responses. This JPO effort was coordinated to complement mission kill investigations that had been previously initiated by DARPA's Defense Sciences Office (DSO) and CRDEC.

The objective of the Mission Kill program was to develop novel means to defeat vehicles, especially main battle tanks; to identify the most promising technologies based on threat vulnerabilities; to integrate mission kill mechanisms into war games for system analysis; and to determine mission-kill feasibility and robustness. The intent was to ascertain whether (1) MK would lead to the ability to defeat main battle tanks without penetrating the armor envelope; (2) rounds would be less sensitive to miss distance, which would increase cost effectiveness; and (3) existing technology could be used to deliver the MK devices, which would also increase cost effectiveness.

There were four technical areas of research in the Mission Kill program: the engine, radiator/air cleaner attack, flame and incendiary research, and the tank shroud. The engine research was a DSO initiative with the goal of engine kill through combustion modification using extinguishers or enhancers. Contractors included Southwest Research Institute, GTRI, Kilgore, TACOM, Wayne State University, Los Alamos National Laboratory, Sandia National Laboratory, and MRC. The radiator/air cleaner attack portion of the program was performed at IIT Research and dealt with the use of explosive foams as an area kill weapon (to stop engines by clogging radiators and air cleaners). Southwest Research Institute researched a man-portable weapon that was designed to burn holes into the lightly armored engine covers and disable tank engines. The munition was to be a combination flame and thermite weapon. The final technical area of the Mission Kill program was the tank shroud developed by Foster Miller; the concept was for a man-portable weapon that would defeat targets without penetration by enveloping the vehicle in a sheet of synthetic polymer, thereby restricting vehicle mobility and eventually stalling the engine and reducing crew visibility.

Another major effort undertaken was the establishment of the Committee for the Technical Review of Mission Kill Initiatives. This committee was given the charter to report to the JPO with recommendations regarding ongoing MK efforts, to identify applicable technologies and applications, and to assess military worth and utility. Key findings of the committee included a definition of mission kill, the review of past and ongoing MK programs, and the establishment of a metric for measuring the effectiveness of mission kill weapons.

For all of the above-mentioned programs, SPC provided support for program planning and procurement, performed military operations analysis and data analysis, organized and hosted several program reviews and conferences, assisted with the preparation of technical reports and documentation, and provided technical library support for this task, which included the handling, storage, and retrieval of classified materials. A final report, *Assessment of Mission Kill Concept, Requirements, and Technologies*, was published by SPC in September 1990.

P. LOCKOUT DEVICES FOR MAN-PORTABLE ANTIARMOR AND ANTIAIR TACTICAL SYSTEMS REPORT SUPPORT

Congress's concern over proliferation of handheld antiair and antiarmor weapons, heightened by events in the Persian Gulf, led to its request for a report on the subject, and ARPA tasked SPC to provide technical and administration support to manage a study and write a report to Congress on lockout devices. To accomplish this task:

- SPC hosted meeting to assemble data for the report.
- Organized inputs of various agencies.
- Prepared draft copies of the report
- Provided final report to DARPA PM for timely submission to Congress.

The final report was forwarded to LSO on 14 May 1991. The following conclusions/ recommendations were made to Congress:

- **Feasibility.** There is no doubt that effective lockout systems are technically feasible and that the technology for their implementation is largely in hand. Different lockout approaches, from physical security to removing pertinent components or equipping weapons with embedded codes that require periodic revalidation, may be required depending on the objective of the lockout; i.e., to deny use of the weapon by terrorists or to prevent effective use following unauthorized transfer or battlefield loss to military forces. In each case, appropriate technical approaches exist. A considerable amount of technical expertise and experience with operational issues is available at the Program Executive Office, Air Defense, Redstone Arsenal, Alabama, and within the Advanced Projects Division IV, at Sandia National Laboratories.

- **Retrofit of Lockout Devices.** Retrofit of lockout devices to existing weapon systems is not recommended. In most cases it would be extremely difficult, costly, and likely to be less than fully effective. Consideration of lockout device implementation for new weapon systems should be made at the very beginning of the acquisition cycle, preferably in the early concept stage. Establishment of an architecture or methodology for decisions regarding implementation of lockout in tactical weapons system is recommended.

Q. GEL PROPELLANT, ADVANCED PENETRATOR, COMPOSITE CASE (GPAPCC) PROGRAM SUPPORT

SPC supported the program manager in this effort by formulating the program plan and developing required funding and contracting packages. An SPC subcontractor, W. J. Schaefer Associates, worked with SPC to provided program management support.

This was a 1-year (February 1991–February 1992), proof-of-principle effort to demonstrate an enhanced small-caliber (12.7-mm), kinetic-energy munition employing (1) a composite cartridge case, to be developed by Ammunition Technologies International (ATI) (based on DuPont lightweight composite polymer work); (2) an advanced tungsten penetrator, to be developed by Lawrence Livermore National Laboratory (LLNL); and (3) a gel propellant to be developed by DuPont. (In fact the propellant to be developed by DuPont was based on their PT-509-A gelled propellant formulation sponsored by ARL. This effort was itself an outgrowth of work done by DuPont in low-sensitivity, ultra-recrystallized explosives under the auspices of the A^3 JPO.) Government testing was conducted at the Naval Surface Warfare Center in Dahlgren, Virginia.

Numerous benefits were hoped to be gained from this effort. The LLNL penetrator, for example, offered increased lethality for smaller calibers. The ATI composite cartridge case offered a potential 30% reduction in weight over conventional cartridges. The DuPont gel propellant itself offered a number of benefits. Because it had a lower flame temperature, little or no residue, and a smooth pressure/time profile, it offered both reduced barrel erosion and recoil. Its low sensitivity offered increased safety. Its lack of smoke and the virtual elimination of muzzle flash increased the survivability of the weapon system. Additionally, the potential of increased batch-to-batch consistency offered the opportunity for lower material costs.

This program also offered several technical challenges. The work on gel propellants was on the leading edge of technology, and little work had been done in the area previously. Two of these technical challenges were the requirement for a nonmetallic or corrosion-proof cartridge case (because the PT-509-A propellant was water based) and the need to increase the impetus of PT-509-A without a concurrent increase in flame temperature. The latency period between firing and ignition of PT-509-A was also too long. Proof-of-principle was not demonstrated. Three hundred sixteen firings employing gel propellant were conducted during this program. Two of these firings included the LLNL advanced penetrator. These two tests indicated that the penetrator was aerodynamically unstable, requiring a redesign. No firings were conducted with the composite cartridge case because initial testing at low pressure resulted in several cases splitting, requiring a redesign.

A number of reformulations of PT-109-A were developed. The most promising of these was GP-10A, the three major constituents of which were ammonium nitrate , PETN, and water. While this was the most promising of these formulations and demonstrated a smooth pressure/time profile and insensitivity, it was found that a smokeless powder booster of ~ 20% of charge weight was still required to overcome the impetus and latency period problems.

Perhaps the major finding with respect to the gel propellant was that considerable work remained to be done on material characterization because the basic phenomena was still not understood. Since sponsorship for continued work on this effort could not be found, it was discontinued. A final report was prepared by DuPont.

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