Current SSD Programs

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SECTION A. STRATEGIC WEAPON SYSTEMS

A1. Fleet Ballistic Missile Test and Evaluation

John P. Gibson

INTRODUCTION

The Navy's Fleet Ballistic Missile (FBM) Strategic Weapon System (SWS) is recognized today as the principal component of the U.S. nuclear strategic deterrent. The submarine-launched ballistic missile (SLBM) on its nuclear-powered submarine platform provides a mobile, long-patrol duration, covert, and invulnerable strategic deterrent force (Fig. A1-1). The FBM system has evolved through several generations of missiles and weapons systems deployed on five classes of submarines. The original fleet of 41 SSBNs has

Figure A1-1. A Trident II (D5) SLBM broaches and ignites during a Demonstration and Shakedown Operation off the coast of Florida.

been replaced with 18 newer Ohio Class Trident SSBNs. Table A1-1 provides the specifications of the six generations of FBMs beginning in 1960. Each generation has been succeeded quickly by a more advanced version, resulting in a mixture of deployed systems for the Navy to sustain and manage. The increasingly complex features of each new FBM/SWS have provided unique challenges in the design and implementation of the test and evaluation program required to validate its capabilities and produce the high level of credibility essential to its national deterrent mission.

APL has assisted the Navy Strategic Systems Programs (SSP), since the inception of the FBM Program, in defining and conducting a continuing test and evaluation effort for each generation of SWS. APL has also assisted the U.K. Royal Navy with evaluations of their FBM fleet, starting with the U.K. Polaris program in the mid-1960s, and continuing through the current deployment of the U.K. Trident SSBN fleet. The results of the U.S. SWS evaluations are provided to the Navy technical and Fleet Commands, which then present them to the U.S. Strategic Command (USSTRATCOM) for strategic targeting requirements. This article describes the current, ongoing efforts of the Strategic Systems Department (SSD) in support of this national priority program.

TEST PROGRAMS

Because of the vital importance of the FBM Program to the national nuclear deterrent force, and the requirement for annual performance estimates, an ongoing test and evaluation approach has been established to monitor these systems throughout their deployed life. APL has assisted SSP in structuring a comprehensive test program and is the principal agent for the continuing evaluation of the FBM weapon system for the Navy. The three primary test programs of the FBM SWS evaluation are (1) Demonstration and Shakedown Operations (DASOs)—testing that is conducted before strategic deployment, (2) patrol—recurring tests conducted during each strategic deterrent patrol, and (3) Commander-in-Chief (CINC) Evaluation Tests (CETs) or Follow-on CETs (FCETs)—

Table A1-1. Specifications of six generations of SLBMs.

	SLBM					
Feature	Polaris A1	Polaris A2	Polaris A3	Poseidon C3	Trident C4	Trident D5
Year deployed	1960	1962	1964	1971	1979	1990
Length (ft)	28.5	31.0	32.3	34.0	34.0	44.6
Diameter (in.)	54	54	54	74	74	83
Weight (lb)	28,000	32,500	35,700	64,000	73,000	130,000
Range (nmi)	1200	1500	2500	2500	4000	4000
Payload	1 RB	1 RB	3 RBs	MIRVs	MIRVs	MIRVs
Guidance	Inertial	Inertial	Inertial	Inertial+ stellar	Inertial+ stellar	Inertial+ stellar
Propulsion stages	2	2	2	2 + bus	3 + bus	3 + bus

Note: RB = reentry body; MIRVs = multiple independent reentry vehicles.

end-to-end weapon system tests, including missile flights, conducted with randomly selected SSBNs periodically throughout the life of the system.

The effective implementation of a comprehensive test and evaluation program is highly dependent on involvement during the earliest design and development phases of the system. To ensure availability of the required test data for the deployed system, identification and integration of necessary instrumentation, testing concepts, and special test procedures must be accomplished during the weapon system design.

SSD has played an important role in defining evaluation and data requirements for each generation of the FBM SWS. Novel system test concepts have been devised, and sensors and instrumentation have been conceived, built, and utilized in this continuing evaluation effort. Recent APL-developed innovations include the introduction of electronic log-keeping devices and a versatile, onboard ship-control training capability (see the article by Biegel et al., this issue). Recurring test and evaluation tasks include the design of individual flight test mission trajectories consistent with current FBM employment concepts, production and maintenance of test procedures unique to each test program and SSBN class, and specialized training sessions for SSBN crews.

The contributions of SSD to the continuing FBM SWS test and evaluation effort are summarized in Fig. A1-2 and discussed in other articles in this issue. To perform these tasks, SSD has maintained a permanent field office at Cape Canaveral, Florida, since 1959, provides an on-site representative to the staff of the Commanders of the Atlantic and Pacific Submarine Forces for required liaison with the operational forces, and maintains a dedicated data processing and analysis facility. The following sections describe the basic components of the FBM SWS test and evaluation program.

Demonstration and Shakedown Operations

DASO exercises are conducted by each U.S. and U.K. SSBN prior to strategic deployment after either new construction or a shipyard overhaul period. This is the first time that the new or upgraded weapon system undergoes full, comprehensive system tests and culminates in a test of the entire system, including missile launch. Interspersed throughout the dockside and at-sea operations are a series of activities and simulated countdowns (many with inserted casualties) to provide realistic training. Objectives of this program are to (1) certify the readiness of the SSBN weapon

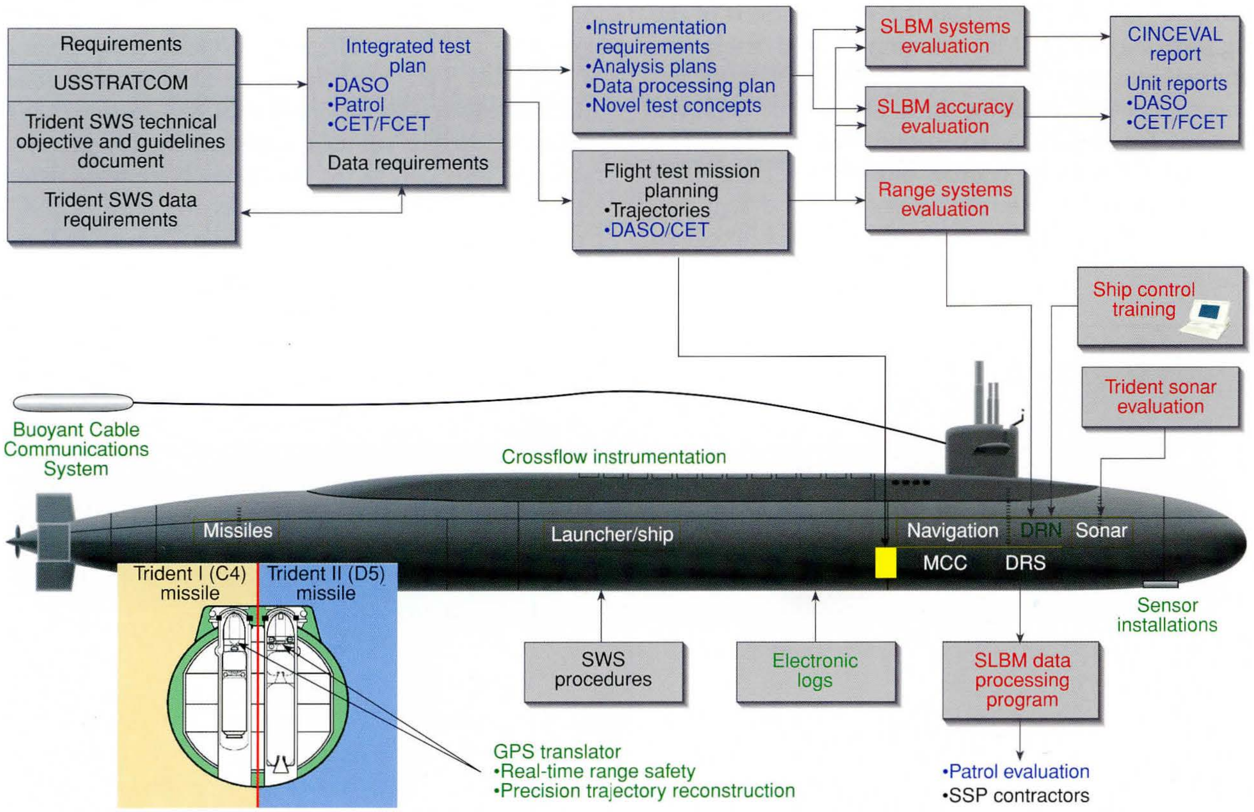


Figure A1-2. SSD contributes to the continuing Navy Fleet Ballistic Missile Strategic Weapon System test and evaluation programs. (SSD-developed hardware, green; documents/reports, blue; programs, red. MCC = master control console, DRS = Data Recording System, DRN = DASO Reference Navigator, CINCEVAL = Commander-in-Chief Evaluation.)

system and its crew for strategic deployment, (2) evaluate the technical performance of the weapon system while in an operational environment, identifying material and procedural deficiencies, and (3) provide data used to derive current reliability and accuracy measures of performance for the deploying weapon system.

APL participates in DASOs by providing a team of up to 14 professional staff members, supported by additional administrative and data processing personnel, at the DASO field site in Cape Canaveral. APL also provides field technical support to the SSP Weapons Evaluation Branch Team tasked to conduct and evaluate each DASO. The DASO simulates all phases of a typical strategic patrol to validate procedures and evolutions that will be conducted during deployment. In addition, SSP-approved special tests are scheduled and performed, as appropriate, to evaluate new capabilities and new equipment, or as diagnostic investigations.

SSD develops, conducts, and evaluates some of these special tests, such as the submarine crossflow evaluation depicted in Fig. A1-3. The crossflow instrumentation measures, records, and provides real-time display of the speed of water across the submerged SSBN missile deck during FBM launch operations or special at-sea tests. This instrumentation allows SSD to evaluate the dynamics of FBM underwater flight throughout the SSBN speed/depth launch envelope. During DASOs, SSD field-test teams evaluate all aspects of the performance for each weapon subsystem (navigation, fire-control, missile, launcher, and ship) and provide the Navy with a technical report documenting the results of that evaluation. This report is generated within 2 weeks of completing each DASO and is used to support the Navy's certification for deployment.

Patrol

Each SSBN and weapon system may be deployed for a decade or more. The continuous monitoring of each SSBN identifies hull-unique problems as well as Fleet trends that may evolve or change with time and affords a current, cumulative weapon system performance estimate, which is critical to maintaining the credibility of this strategic deterrent system. The objectives of patrol evaluations are to (1) provide FBM weapon system performance information in the actual patrol environment for use in deriving USSTRATCOM performance planning factors, (2) provide Navy Fleet

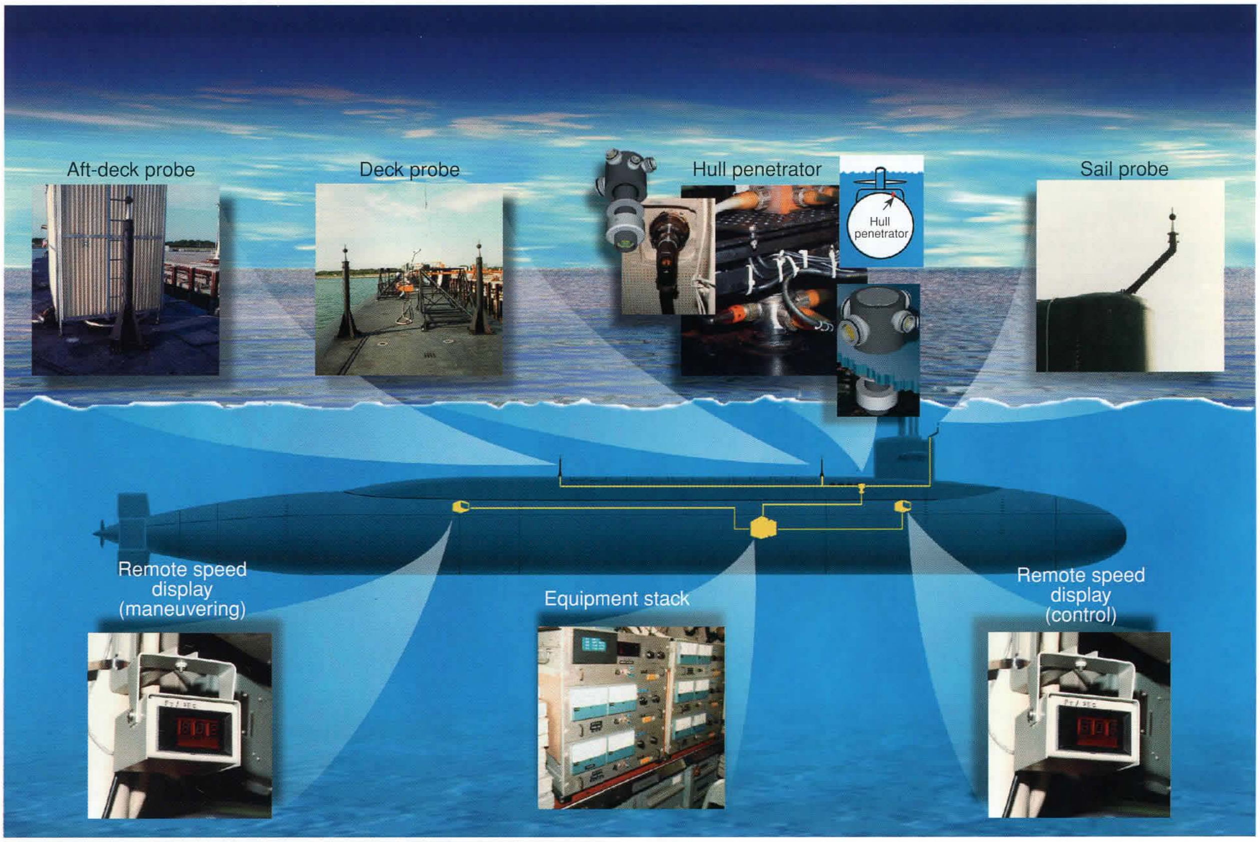


Figure A1-3. APL-developed crossflow instrumentation (see Fig. A1-2) is used during a DASO to measure, record, and display real-time water speed across the SSBN missile deck during an SLBM launch.

Operational Commanders and SSP with an independent system evaluation of each SSBN and its weapon system while on strategic deterrent patrol, and (3) provide individual SSBN crews with an analysis of the performance of their weapon system during patrol.

While on patrol, the submarine regularly conducts tests that activate the weapon system in a manner similar to an actual countdown to launch (but with appropriate safeguards in place). In addition, tests that monitor the health of each subsystem along with routine maintenance are conducted regularly. Data from all of these sources, both electronically recorded and manually logged, are sent to APL after each patrol. Engineers and analysts review raw and processed data to identify equipment problems, faults, and other abnormal conditions and to initialize simulations used in the patrol evaluations.

SSD has developed a set of electronic data-logging devices for SSBN crews. These electronic logs are replacing the traditional paper ones and will increase efficiency in documenting and evaluating patrol activities. Electronic data from the individual navigation, fire-control, launcher, and control and monitoring panel logs are transferred to the Electronic Weapons Log (EWL) base station at the end of each watchstander's shift. The EWL base station maintains the historical log record onboard the SSBN and allows the crew to use these files for analysis. EWL data are copied to compact disc and transferred to APL at the end of each patrol or upkeep cycle. After the patrol data package is reviewed, patrol and upkeep quicklook reports are produced to provide an overview of in-port and underway activities and problems that may need attention before the next patrol. A more detailed patrol summary report gives a synopsis of each subsystem's performance throughout the period and provides the data from which hull-unique or class performance trends are examined.

Certain patrols are evaluated randomly in greater depth, consistent with the need to obtain information to form credible annual estimates of weapon system performance. APL engineers meet with the crew to review the evaluation and confirm interpretation and understanding of the logged activities. After this review, a final patrol report is published and distributed to SSP and its contractors, the Operational Commanders, and the submarine crew. The data and evaluations from these patrols contribute to the APL annual weapon system performance estimates that are used by USSTRATCOM to prepare strategic targeting.

CET/FCET

The CET/FCET is the continuing operational test program conducted annually with randomly selected SSBNs. The results of these tests, which include the launch of multiple test-configured FBMs, provide the basis for the annual performance estimates of the FBM SWS. The objectives of this program are to (1) determine operationally representative weapon system performance characteristics for targeting purposes, (2) ensure that planning factors do not significantly change with time, (3) determine the adequacy of tactical procedures, and (4) provide diagnostic information that may lead to system improvements.

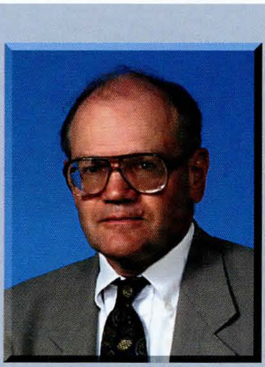
Without advance notice, a selected SSBN is recalled from patrol for a CET. Two or more missiles, selected randomly from the onboard complement of tactical missiles, are converted to a test configuration alongside the wharf at the normal refit site. Following this evolution, the submarine proceeds to a launch area and resumes operations as if on a strategic deterrent patrol. The USSTRATCOM transmits an exercise launch message at random via the strategic communications links. When the message is received, the submarine, using tactical procedures, launches the designated CET missiles at the tactical firing rate. Data obtained from instrumentation onboard the SSBN, from a launch area support ship, and from downrange support sites (on ship, aircraft, and land) provide the information necessary for SSD engineers to assess total weapon system performance in this near-tactical end-to-end test.

An APL representative meets the submarine when it returns from the exercise to review the operation with the crew, inspect the condition of the weapon system, and provide a quicklook report to the Navy on the overall operation. A team of APL engineers conducts a subsequent detailed evaluation of all the data from the exercise, and a report covering the entire test operation, including missile performance during flight and reentry, is provided to the Navy.

The evaluations that APL performs for these three major test programs (DASO, patrol, and CET/FCET) provide the complete data set necessary to derive current weapon system planning estimates that are prepared annually for the CINC evaluation reports. These annual reports are prepared for the cognizant CINC of each SWS in accordance with evaluation guidance specified by USSTRATCOM. For the FBM Program, APL has prepared them for the CINCs of the Atlantic and Pacific Fleets since 1966. The CINC evaluation reports are forwarded by those commands to USSTRATCOM for use in the annual strategic targeting laydown. They provide estimates of weapon system prelaunch, in-flight, and reentry reliability, accuracy, reaction time, launch interval, and missile performance capabilities. A detailed discussion of the validity of the test program and the sources of demonstrated performance data used in developing the estimates is also provided, as required by USSTRATCOM.

These APL-generated reports provide an annual assessment of the complete FBM SWS for the nation's strategic planning processes. Future generations of the FBM SWS will most likely be developed in an entirely different manner than earlier generations, i.e., their development will be more evolutionary and involve less whole-system replacement. Furthermore, the complexity and cost of these advanced strategic weapons will undoubtedly limit the number of full-scale tests that can be conducted. The ability to test and demonstrate system capability to potential adversaries will nevertheless remain a crucial element in the credibility of these strategic deterrent systems. Therefore, the Laboratory must continue to develop and implement improvements to its test and evaluation approaches. The challenge will be to execute this continuing, nationally important task efficiently and cost-effectively while maintaining the credibility that has been the hallmark of APL's contributions to the FBM Program.

THE AUTHOR



JOHN P. GIBSON is a member of APL's Principal Professional Staff. He received a B.S. degree in aerospace engineering from the Pennsylvania State University in 1964, and an M.S. degree in aerospace engineering from Drexel University in 1967. Since joining APL in 1967, he has worked in the Strategic Systems Department. Mr. Gibson has served as Program Manager for the Trident I (C^4) Strategic Weapon System Evaluation and as Program Area Manager for the Strategic and Tactical Systems Programs. His e-mail address is john.gibson@jhuapl.edu.

A2. The Fleet Ballistic Missile Accuracy Evaluation Program

Dean R. Coleman and Lee S. Simkins

BACKGROUND

In the early 1970s the Navy was asked to respond to a DoD request to produce a development plan for a future highly accurate FBM Strategic Weapon System (SWS). The Trident I SWS, then in development, as well as its predecessors (Polaris and Poseidon), were designed to meet accuracy goals that were well within the existing state-of-the-art. The observed system accuracy for each generation of FBM met those goals but was not thoroughly explainable. As a result, insight was lacking into the technical limitations on the incremental improvement in accuracy that might ultimately be achieved in an advanced system (Trident II). In order to plan a set of design options with confident, quantifiable accuracy improvements, the Navy needed an improved technology base. In 1975, Strategic Systems Programs (SSP) initiated an Improved Accuracy Program to gain the understanding and tools necessary to validate the accuracy of the design options as well as the instrumentation needed to evaluate a new high-accuracy system.

SSD played a leading role in the Improved Accuracy Program over its 8-year course, fulfilling a system evaluation task for the Navy in helping to achieve the accuracy technology base for Trident II. Advanced instrumentation, data processing, and error estimation techniques were developed by SSD together with other members of the Navy/contractor team and were used to gain insight into the sources of inaccuracy during flight tests of the Trident I weapon system, which provided the springboard for Trident II development concepts.

An SSD system-level accuracy model validation effort, in conjunction with subsystem-level investigations by hardware contractors, led to high-fidelity analytical accuracy models that were used in Trident II trade-off studies. SSD long emphasized to the Navy the importance of accuracy instrumentation, in particular, to enable errors to be sufficiently visible so that test results could be extrapolated to untested, tactical conditions.

APL was asked to determine the instrumentation and evaluation concepts that would be needed for Trident II to ensure a high-confidence accuracy evaluation capability. Through a joint effort between APL's Space Department and SSD, the Accuracy Evaluation System for Trident II was defined by early 1982. A satellite-based instrumentation system known as SATRACK had been conceived by APL in the early 1970s and proven in Trident I applications. It would become the backbone of SSD's evaluation capability for the advanced Fleet Ballistic Missile Strategic Weapon System.

TRIDENT II AND ADVANCED SYSTEMS

The stringent Trident II accuracy performance objectives motivated the development of demanding performance evaluation criteria and objectives. The Navy's desire to understand the system's performance with high confidence was translated into several specific accuracy evaluation objectives. These had significant implications with respect to analysis methodology, instrumentation, and modeling and simulation.

The Accuracy Evaluation System study outlined the process for attacking the accuracy evaluation problem. First, the evaluation objectives required that system performance be estimated. It would no longer be sufficient to use model validation approaches wherein test data were used to validate or invalidate contractor-supplied performance models. Without a methodology that provided direct estimates of parameter values, knowing that a model was to some degree invalid begged the question: If the current model is invalid, then what is the better model? Thus, model parameter estimation was established as the fundamental approach, and the method of "maximum likelihood" was adopted as the preferred methodology for identifying accuracy parameters from test data.

The requirement to estimate performance did not end there, however. Quantified confidence was also necessary. There had to be a procedure by which the uncertainty with which we observe performance as well as the finitude of test programs was translated into specified confidence (or uncertainty) in the accuracy parameters being estimated. Information theory provided the basis for developing algorithms that could quantify the confidence with which accuracy would be estimated. Next, performance was required to be known, and not just at the system level. The accuracy evaluation system had to be able to isolate faults and estimate performance of the subsystems or the various phases of the weapon system. This required that instrumentation and measurements be made not only at termination (e.g., reentry vehicle impact or airburst) but also during tactical patrol and at every phase of a full system test (prelaunch, powered flight, reentry body deployment, free-fall, and reentry). Figure A2-1 depicts the current Trident II flight test instrumentation suite.

Since the number of allowable tests used for the determination of estimates was specified at fairly low-to-modest levels (about 10 to 20 tests), the instrumentation had to be of sufficient quality to provide the high-confidence estimate; thus, a high-level goal was established to maximize information from the expensive and limited flight test samples. In addition, the evaluation objectives required that we be able to extrapolate to untested conditions, that is, to predict tactical performance, with high quantified confidence, from test data.

The need to predict tactical accuracy from test data had a profound impact on how the modeling was performed. Accuracy contributions had to be modeled at a fundamental level, independent of the test environment. For instance, inertial guidance errors would be characterized and modeled in detail at the hardware component level, i.e., complete mathematical descriptions (including cross-coupling and higher-order terms) of the input/output characteristics of the individual gyro and accelerometer hardware, component misalignments, etc. The structure of these detailed error models was derived from physics, first principles, or contractor component and subsystem tests. However, the values of the parameters would be derived from demonstrated operational test data.

In some cases, it was impractical or unnecessary to require modeling at such a level or to restrict data sources to flight tests. Additional sources of "demonstrated" data to supplement the flight testing were devised. For example, a novel approach for gathering representative navigation data, called the Navigation Accuracy Test, was developed by SSD to be conducted periodically during strategic deterrent patrols. Procedures and instrumentation were developed so that navigation contributions to system inaccuracy could be ascertained from simulated system countdowns during tactical alert periods; a missile did not need to be launched in order to understand a ship's navigation performance. This approach would provide significant insight and more data samples than would have been available if the evaluation were limited solely to the missile flight test program.

Data from each accuracy test were analyzed using some variant of a Kalman filter. Within the filters are the detailed models of both the system and instrumentation for each subsystem. Figure A2-2 depicts notationally how this analysis is accomplished. Given a particular test or scenario (say, a flight test) measurement data are collected on the various subsystems. Using rigorous methods, these data are combined with prior information generally developed and maintained by contractors responsible for various parts of the system under test. This prior information is necessary for single test processing, given the incomplete observability of error sources.

The outputs of the filter provide a basis for understanding particular realizations of system and subsystem

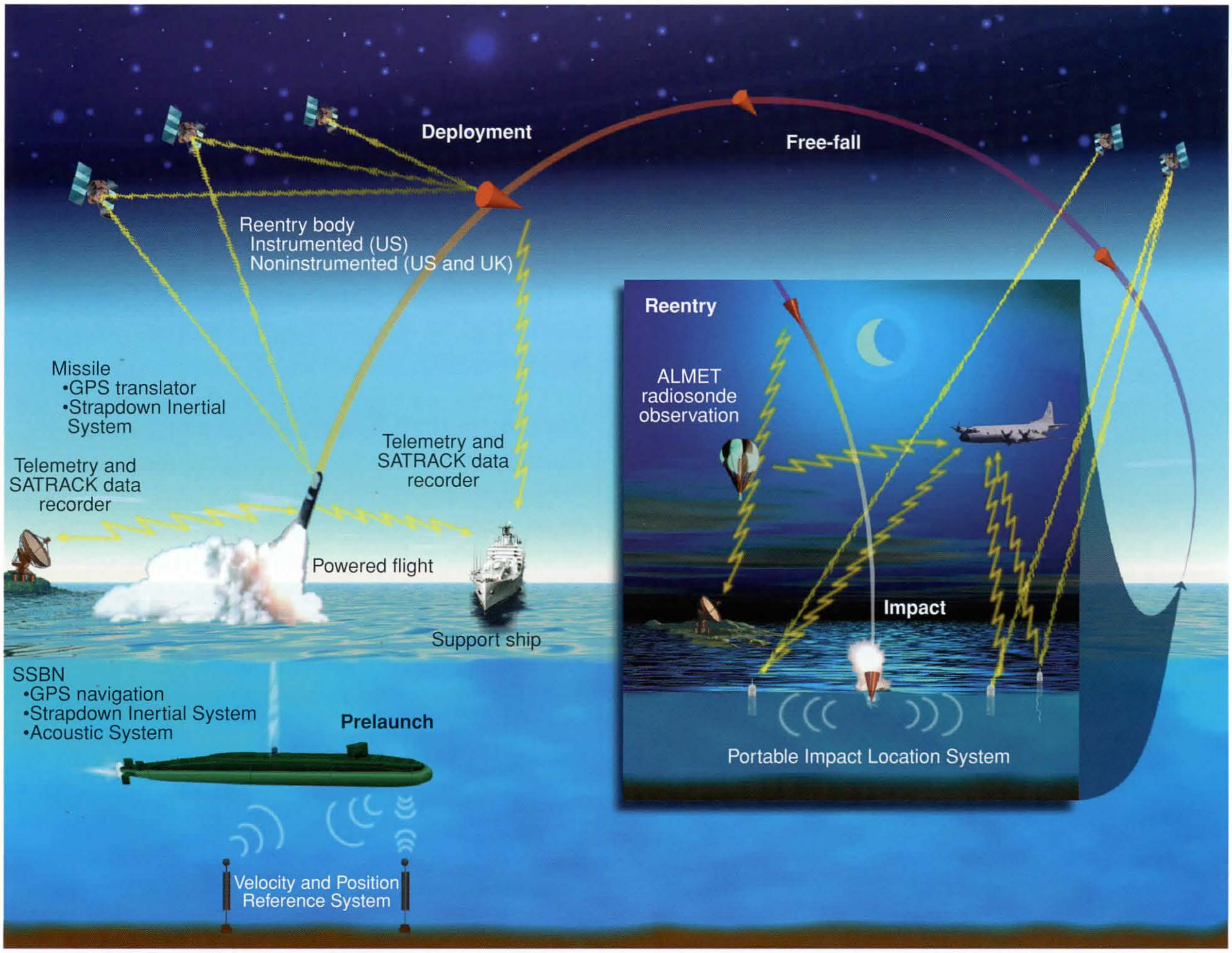


Figure A2-1. Current Trident II (D5) accuracy instrumentation suite. Measurements are made at every phase of a full-system test. (GPS = Global Positioning System, ALMET = Air-Launchable Meteorological System.)

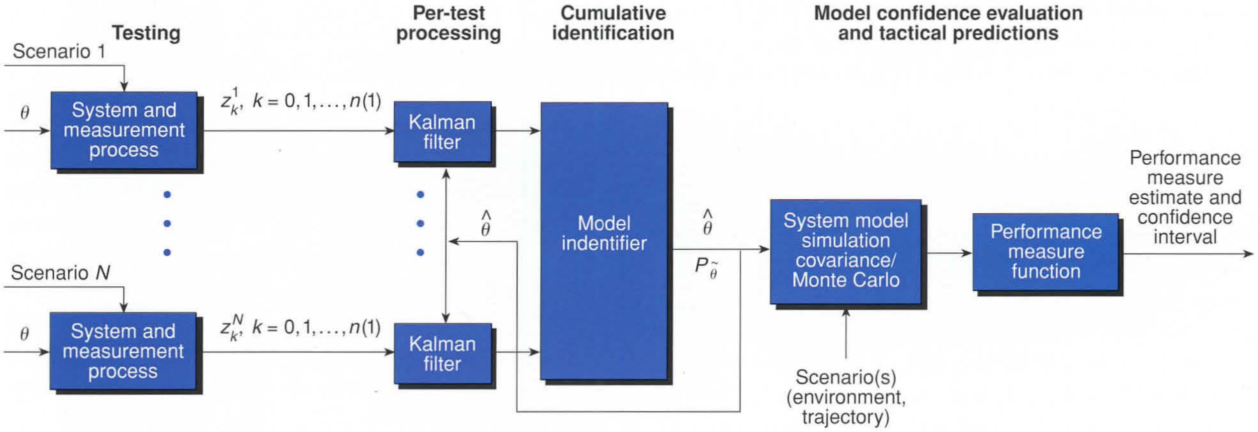


Figure A2-2. Strategic Weapon System accuracy evaluation concept. θ = model parameter, $\hat{\theta}$ = estimate of parameters derived from tests, $P_{\tilde{\theta}}$ = estimation error covariance matrix, z_k^j = measurement k from test j.

behavior. Analysis results provide insight into the sources and causes of inaccuracy (Fig. A2-3). The results of multiple tests (the outputs of the Kalman filters) serve as input to the cumulative parameter estimation process; however, all prior information relative to the error models is removed so that the estimated accuracy is derived solely from the test data.

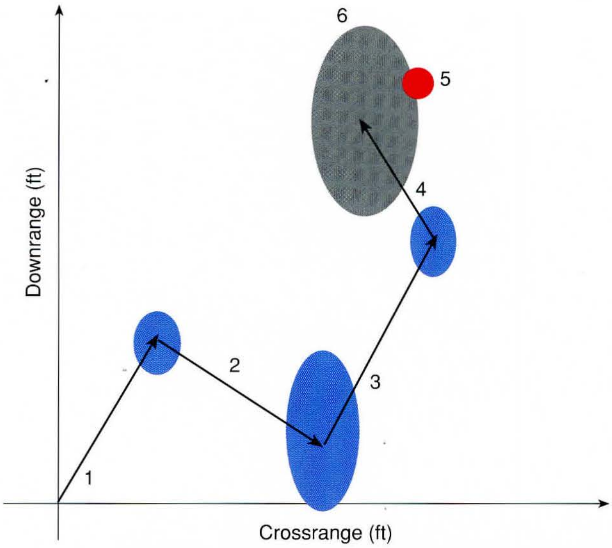


Figure A2-3. Reconstruction of sources of missile impact miss distance error. 1 = initial conditions, 2 = guidance, 3 = stellar residual, 4 = deployment, 5 = reentry body measured impact, 6 = total uncertainty.

This process solves the highly nonlinear equations for the means, variances, and Markov parameters that characterize the overall system accuracy performance. In addition, uncertainties in the parameter estimates are calculated so that we have a quantitative measure of our confidence in the solution. The ultimate desired product is a performance prediction for the system under tactical, not test, conditions. Here we rely on models of the tactical gravity and weather environment developed from data and instrumentation. These models, along with deterministic simulations of the system, are then used to "propagate" the fundamental model parameter estimates and uncertainties to the domain of interest—system accuracy at the target.

TECHNOLOGY ADVANCEMENTS

The development, maintenance, and evolution of the Trident II Accuracy Evaluation System provided considerable technical challenges in terms of methodology, numerical methods, mathematical modeling, algorithms, software, and instrumentation. Noteworthy developments include constrained numerical optimization algorithms; efficient gradient approximation techniques; large-scale, efficient, and numerically stable filtering algorithms; high-fidelity models and simulations of inertial guidance, navigation systems, and gravity; the use of the Global Positioning System (GPS) for precision tracking; development of GPS translator concepts and hardware; advancements in GPS signal tracking and receiver technology; modeling and development of precision acoustic reference systems; and target pattern optimization. Many of these developments have been extended to other weapon systems and programs, including the Air Force's Peacekeeper ICBM, the Army/Ballistic Missile Defense Organization (BMDO) Exo-atmospheric Reentry Interceptor System, and the ongoing test and evaluation of the BMDO exo-atmospheric kill vehicle.

PRINCIPAL ACHIEVEMENTS

The Trident II Accuracy Evaluation Program has contributed to the success of the SWS in several important ways.

Instrumentation Requirements and Test Planning

While in the early development phase, models and simulations of accuracy evaluation processes supported rigorous quantitative trade-off studies designed to support management decisions about instrumentation and test program requirements.

Accuracy Understanding

Analysis has provided unprecedented understanding of and confidence in system performance. The analytical accuracy model has been refined to where current performance is faithfully predicted and is known to be a fraction of the original objective. Biases have been isolated and estimated. System use is enhanced by virtue of our understanding system performance as a function of the tactical operational and environmental parameters. Anomalous test performance has been more easily detected, and causative factors have been isolated.

System Improvements

Improved models and understanding of accuracy provide improved system performance by way of embedded system software. The calculation of system gains used when processing guidance stellar sightings or reentry body fuze information relies on an accurate characterization of system performance. The calibration of reentry body release parameters has been improved by knowledge gained from onboard inertial instrumentation. Accuracy enhancement potential through modified operational scenarios has been demonstrated to be viable.

Accommodation of Testing Cutbacks

Proper instrumentation and a rigorous analytical approach required less testing to achieve the desired initial confidence. In addition, follow-on testing of the deployed system was reduced without significant risk as a result of near-optimal use of the limited flight test assets.

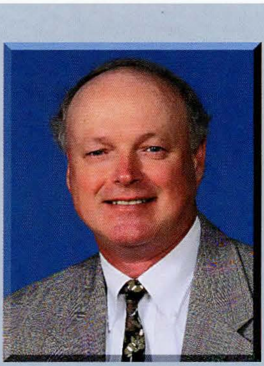
FUTURE DIRECTIONS

In the last several years, there has been considerable interest in a GPS/Inertial Navigation System as both instrumentation and as a candidate tactical missile or reentry body guidance system. Several special tests of missiles and reentry bodies have been conducted with various combinations of inertial systems (space-stable and strapdown), GPS receivers, and GPS translators, as well as various RF/antenna designs. Technologies have been developed to enhance and extend signal-tracking capabilities further, including during periods around onset of plasma blackout and recovery following blackout. Interest in achieving even greater accuracy has been facilitated by the detailed understanding of Trident II performance. Special tests have demonstrated that accuracy can be achieved to support potential new and extremely demanding tactical strike scenarios. Sophisticated tools for exploring optimal target patterning have been developed to support these studies.

Future FBM systems may look very different from present systems. Current modeling and simulation efforts are drawing upon Trident II experience to predict and trade off system design options. Techniques for properly merging ground test (e.g., centrifuge test) data with flight data are being developed in response to the changing test and evaluation environment, where there is much emphasis on affordability and cost reduction. Technology and hardware that support precision intercept system evaluation have been demonstrated, extracting from Trident II technology and extending it through independent research and development projects.

The success of the Trident II system and the Accuracy Evaluation Program is due, in large measure, to SSP leadership. SSP's desire to mitigate risks in the development and maintenance of a high-accuracy strategic deterrent created a vision for an evaluation approach developed as an integrated part of the system. Instrumentation, analytic methods, and modeling and simulation were exploited to optimize the procurement and use of limited and expensive flight test assets. The program has been, and continues to be, successful in meeting its objectives.

THE AUTHORS



DEAN R. COLEMAN is manager of the SLBM Accuracy Evaluation Program within APL's Strategic Systems Department. He received his B.S. in mathematics from the University of Maryland in 1970 and M.S. degrees from The Johns Hopkins University in 1972 and 1985 in numerical science and technical management, respectively. Mr. Coleman has over 30 years' experience in test and evaluation of the Navy's Fleet Ballistic Missile weapon systems. His work has included complex system modeling and simulation as well as evaluation methodology development. Since 1980, he has focused on system accuracy evaluation, where he coordinated APL's SLBM Improved Accuracy Program Analysis Plan and led the Laboratory's efforts to apply this methodology initially to evaluate Trident I and subsequently to evaluate the high-accuracy Trident II weapon system. His e-mail address is dean.coleman@jhuapl.edu.

LEE S. SIMKINS is a member of APL's Principal Professional Staff. He received a B.S. in aerospace engineering from the University of Michigan in 1972 and an M.S. in mechanical engineering from the University of Maryland in 1977. Since joining the Laboratory in 1972, he has worked in the Strategic Systems Department. Mr. Simkins is the Supervisor of the System Development, Test, and Evaluation Branch. For most of his career at APL, he has contributed to the development, implementation, and use of system identification and estimation methodologies that allow the evaluation of submarine navigation, missile guidance, and other military systems. Those efforts have made extensive use of the Global Positioning System as well as other instrumentation consisting of telemetry, inertial systems, and external reference information. His e-mail address is lee.simkins@jhuapl.edu.

A3. Test Range Systems Development and Testing

R. Gilbert Buckman, Jr., and Jerome R. Vetter

INTRODUCTION

The SSD Range Systems Program provides an independent evaluation of all Navy Strategic Systems Programs (SSP)–sponsored test instrumentation systems required to support the Fleet Ballistic Missile (FBM) Flight Test Program. This work also includes evaluating all SSP contractor-developed range instrumentation and software systems necessary to support the program. APL acts as SSP's independent systems test agent for the development, validation, and continuing support of instrumentation systems in the following areas: flight test range safety; real-time tracking systems; range command, control, and communications systems; telemetry; reentry body impact location and scoring systems; meteorological support; and submarine position and velocity determination. An overview of range instrumentation systems currently used to support Trident FBM flight testing is presented in Fig. A3-1.

Recent system development activities have included the Demonstration and Shakedown Operation (DASO) Reference Navigator, the SSBN Buoyant Cable Communications System (BCS), the BCS receive/transmit amplifier, the Global Positioning System (GPS) Air-Launchable Meteorological (ALMET) System, and the Portable Underwater Reference System (PURS). These instrumentation systems support the launch, midrange, or terminal impact areas of an FBM flight test. The SSD Range Systems launch area

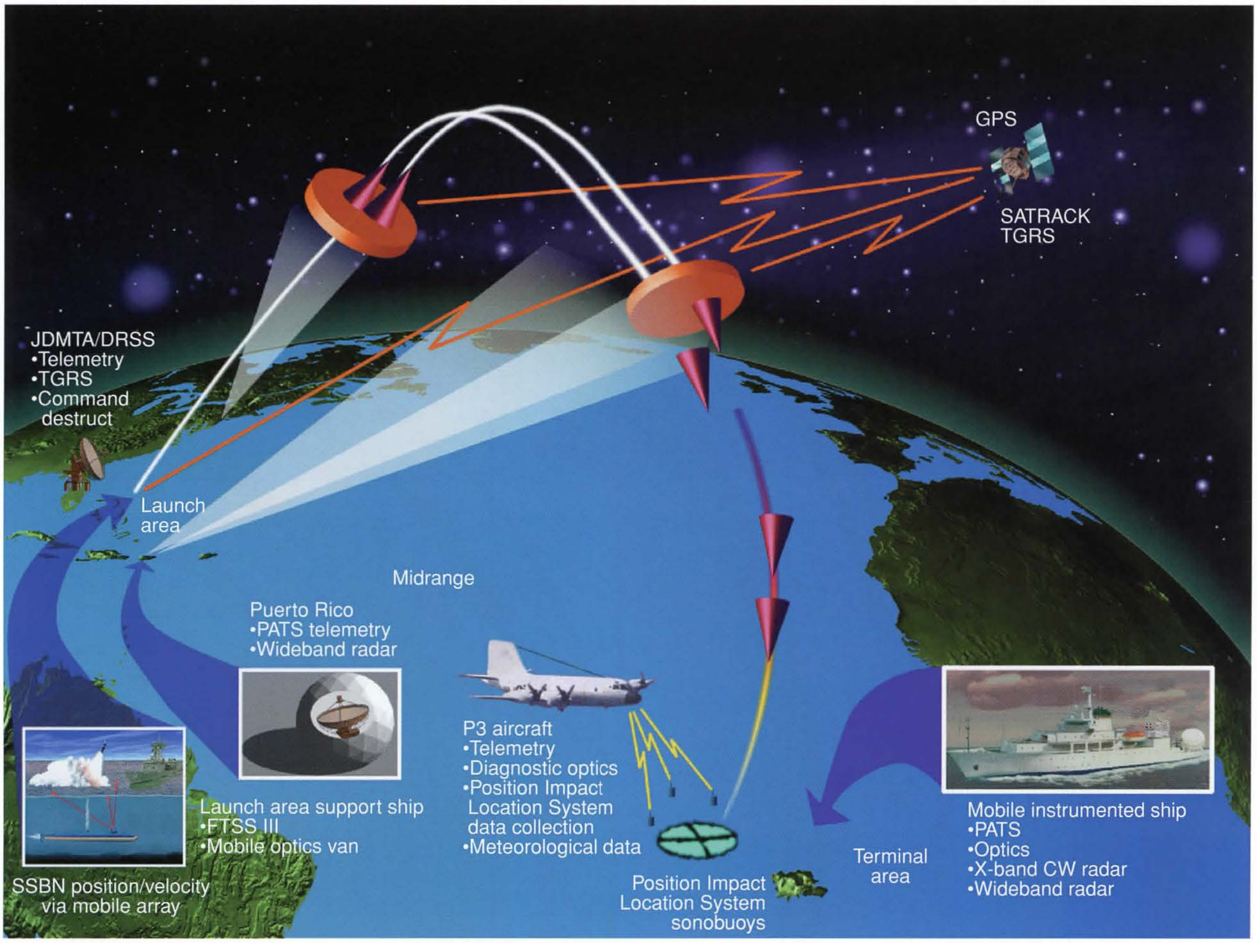


Figure A3-1. Trident flight test instrumentation. The current suite of range instrumentation used to support the Trident FBM Flight Test Program is segmented into three phases of flight: launch, midrange, and terminal. The Navy P3 Orion aircraft, now used in the terminal area, will be replaced by a Navy ship-of-opportunity with an improved, portable instrumentation suite to collect telemetry, optics, radar, weather, and reentry body impact scoring data. (JDMTA/DRSS = Jonathan Dickinson Missile Tracking Annex/Down-Range Support Site; PATS = Phased Array Telemetry System; TGRS = translated GPS Range System; CW = continuous wave; FTSS = Flight Test Support System; GPS = Global Positioning System.)

and terminal area instrumentation projects are shown in Figs. A3-2 and A3-3, respectively, and are discussed in the following subsections.

The development, evaluation, and validation of prototypes for each of these systems were initiated and matured by SSD, and then transferred to the Navy for operational use. Recent evaluation activities have included verification and validation of the real-time tracking and telemetry systems for the Navy's third-generation Flight Test Support System (FTSS III) and the validation of a GPS–sonobuoy Portable Impact Location System for reentry body impact accuracy determination.

LAUNCH AREA INSTRUMENTATION

Submarine Communications System

The BCS provides a modified, towed buoyant cable antenna that allows two-way voice and digital data communications between a submerged submarine and either a surface support ship or an aircraft. It was designed to overcome limitations of the existing radio-frequency and underwater acoustic communications systems. The acoustic systems often limited the standoff range between the launch area support ship (LASS) and the submerged submarine. Connectivity at launch depth is required to coordinate DASO and Follow-on Commander-in-Chief Evaluation Test (FCET) flight test launch operations.

The BCS enables two-way connectivity throughout the depth/speed regime allowed with a standard submarine receive-only floating wire antenna. Special APL-designed "birdcage" antennas located on the LASS afford an adequate radio link with the submarine buoyant cable antenna receive/transmit element floating on the sea. Special tests of BCS connectivity to a Navy P3i Orion aircraft have also been conducted (Fig. A3-2a). Bidirectional voice and digital data have been transmitted between a submerged SSBN and LASS at distances of up to 30 km. SSD designed and built the BCS and the interfacing data acquisition units that were installed on the Trident SSBN and LASS.

The first operational use of the BCS during a missile launch was in support of the USS *Michigan* (SSBN

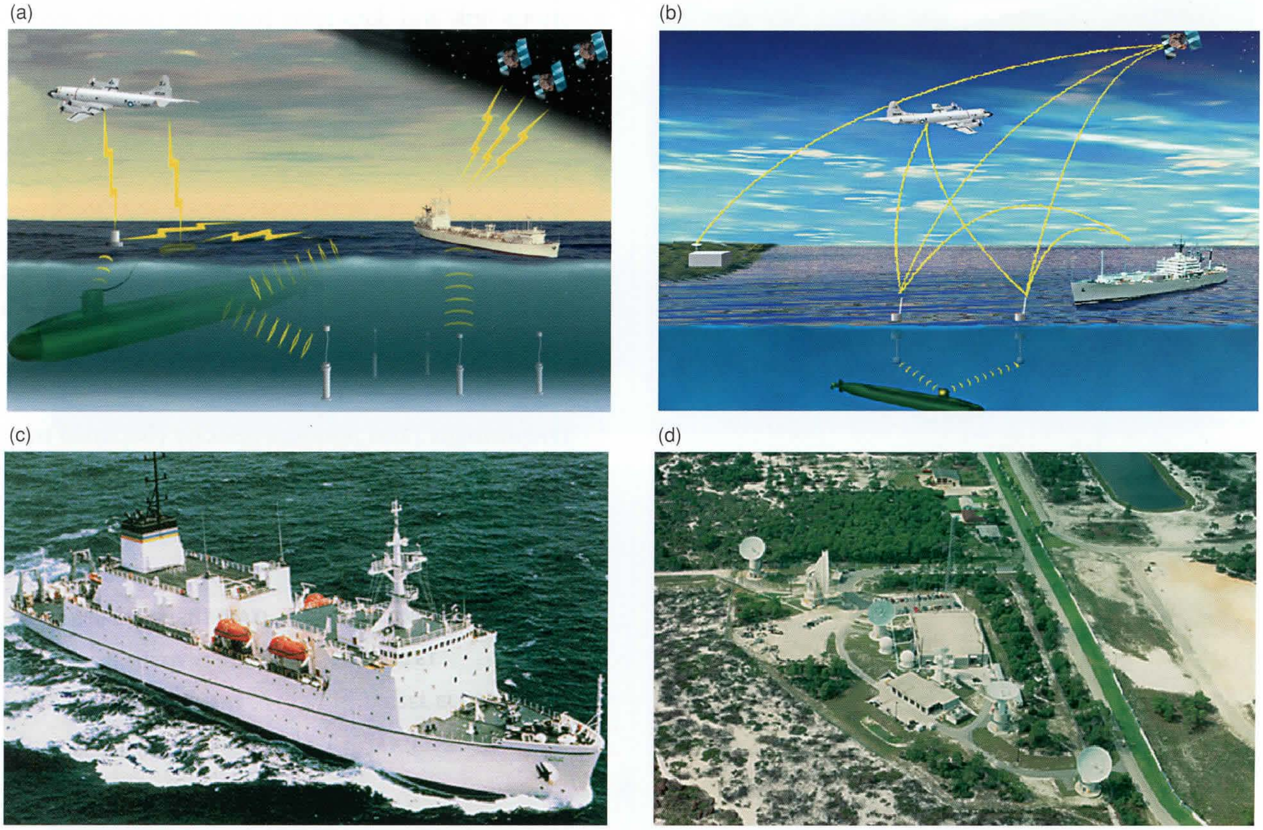


Figure A3-2. Launch area portable range instrumentation. (a) The submarine Buoyant Cable Communications System (BCS) is used for two-way communications with the launch area support ship (LASS), and (b) the Portable Underwater Reference System provides real-time submarine position determination. The Flight Test Support Systems (c) on the LASS (USNS *Waters*) and (d) at the Jonathan Dickinson Missile Tracking Annex Down-Range Support Site ground station provide the eastern Range Command and Control Center at Cape Canaveral, Florida, with real-time data for range safety purposes.

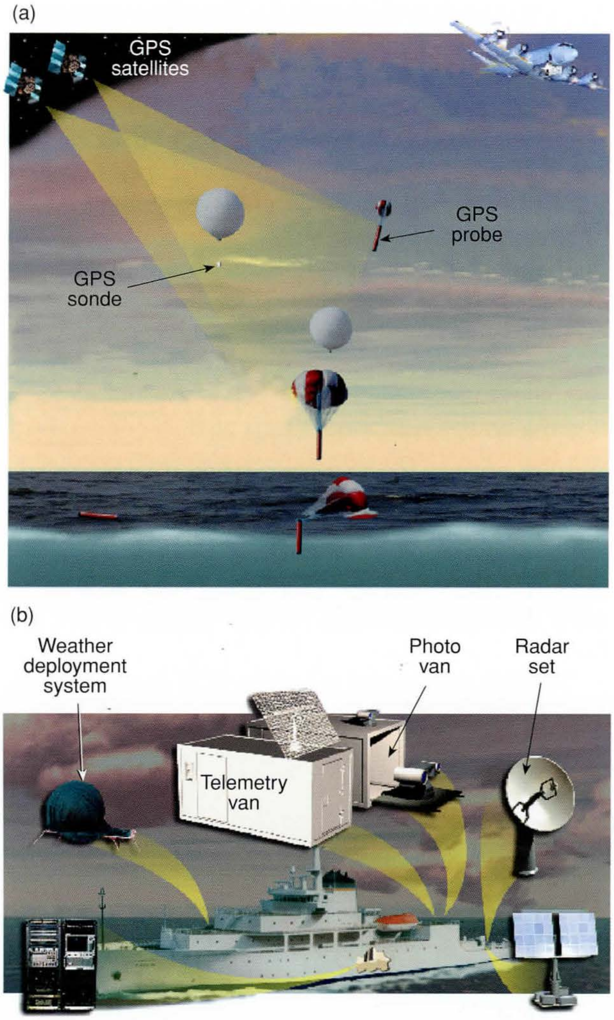


Figure A3-3. Terminal area range instrumentation. (a) The Navy currently uses a terminal area aircraft to deploy the Portable Impact Location System sonobuoys for reentry body impact scoring, launch the Global Positioning System (GPS) air-launchable meteorological (ALMET) probe for meteorological data, and collect instrumented reentry body telemetry when applicable. (b) A more versatile, improved Navy Mobile Instrumentation System, located on a Navy TAGS-60 class ship, will replace the aircraft functions while adding a terminal area tracking capability.

727) DASO in October 1995. Subsequently, the BCS has been installed and used onboard the USS *Maine* (SSBN 741), USS *Wyoming* (SSBN 742), and the United Kingdom SSBN HMS *Vigilant* to support FBM DASO flight test operations. During this period, SSD staff operated the BCS in a test mode. However, the system is currently being transferred to the Navy for future operational use during FCETs.

Portable Underwater Reference System

SSD is evaluating the use of an expendable GPS–sonobuoy system, deployable from a ship or aircraft in the launch area, as a potential replacement to the existing system, the fixed, bottom-mounted Position-Velocity Deep Ocean Transponder (PVDOT). The launch-area PVDOT arrays provide a velocity-position reference system for the submerged SSBN during FCET, but are costly to implant, survey, and maintain. PURS is a cost-effective, versatile alternative to the PVDOT arrays (Fig. A3-2b). Originally developed under an SSD independent research and development project, PURS was successfully transferred to direct Navy sponsorship in 1997. A set of APL-built prototype PURS sonobuoys was tested as part of a deep-ocean demonstration exercise in December 1997. PURS is planned for use as a ship-deployable alternative to the P3 aircraft-deployable Velocity/Position Reference System Replacement System in 1999.

Flight Test Support System III

The FTSS III is a portable system consisting of two vans that can be temporarily installed on Navy ships-of-opportunity and used to support at-sea missile flight tests. A typical FBM flight test uses both a LASS and a downrange support site (DRSS) to provide for continuous tracking coverage (Figs. A3-2c and d, respectively). The FTSS III system supports the collection of real-time FBM telemetry, provides a real-time communications link and data relay from the launch area to the USAF Eastern Range Operations Control Center via the International Maritime Satellite, and will support a real-time GPS tracking capability to satisfy in-flight range safety requirements. The FTSS III tracking system element includes a GPS translator-processor located on both the LASS and at an Eastern Range ground station (Jonathan Dickinson Missile Tracking Annex), which simultaneously receive data from all GPS satellites in view as well as in-flight signals from the missile-borne GPS translator. These data provide real-time precision missile tracking for range safety calculations.

The in-flight FBM position/velocity (obtained from GPS data and FBM telemetry) is compared to a nominal mission trajectory profile developed during preflight mission planning to detect abnormal in-flight trajectory deviations that could require safety destruct action. APL develops the overall FBM flight test program, which contains a variety of mission options in a DASO/CET targeting library, and provides the community with the mission parameters used to derive the nominal preflight trajectory for range safety. The SSD Range Systems Program conducts a validation of the flight test mission parameter data tapes used by the range to ensure that the proper reference trajectory is implemented.

The Range Systems Program has been involved in the verification and validation of all facets of the FTSS III. SSD developed the FTSS III Quicklook System to provide timely unit reports on each FBM launch to assess FTSS III subsystem problem areas and the quality of data from the instrumentation systems used to support the launch. The Quicklook System processes both telemetry and tracking systems data and provides a rapid evaluation of missile trajectory events, abnormal differences between telemetry and state-vector data obtained from GPS, and real-time angle-tracking performance. The LASS and DRSS FTSS III include an updated SATRACK III recording capability which has been validated by APL.

TERMINAL AREA INSTRUMENTATION

GPS-ALMET Probe

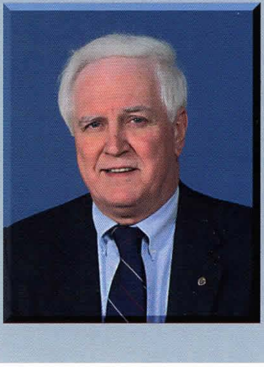
SSD has completed an effort to replace the current ALMET probe that utilized the Omega navigation system, which was phased out in September 1997, with an improved GPS-based probe, GPS-ALMET. The probe is dropped from a Navy P3 Orion aircraft, parachutes to the ocean surface where a helium-filled balloon carrying a radiosonde is released, and ascends while transmitting meteorological and GPS data to the aircraft. Figure A3-3 includes a conceptual overview of its use in the flight test impact area. The GPS-ALMET provides improved position, wind-vector, and meteorological measurements as a function of altitude for reentry analyses. The GPS-ALMET was recently deployed to support DASO flight tests with HMS *Vigilant*.

Navy Mobile Instrumentation System

APL was asked to act as the system integration agent for the new SSP Navy Mobile Instrumentation System (NMIS). The NMIS will provide a modern, mobile, and portable test range instrumentation system to support radar tracking, telemetry acquisition, optics, weather, and communications requirements for Trident missile launches in any ocean. It will use the recently commissioned TAGS-60 class of Naval Oceanographic Service ships as the platform, allowing flexibility for use in any operating area. The NMIS concept was partially tested in December 1997 to support the *Vigilant* DASO in the terminal impact area by using a mobile X-band radar tracker and GPS-ALMET ship-based deployment system.

THE AUTHORS

R. GILBERT BUCKMAN, JR., is the Range Systems Program Manager in SSD. He received a B.S. degree in mechanical engineering from Virginia Polytechnic Institute and State University in 1962 and an M.S. in technical management from The Johns Hopkins University in 1984. Mr. Buckman joined APL in May 1965, and from 1966 to 1968, he was Assistant Supervisor of the APL European Field Office in Heidelberg, Germany, where he developed an automated data collection and transmission system. He has been a group and program supervisor and has been responsible for the development of many innovative, cost-effective projects for the Navy SSP. Mr. Buckman's e-mail address is ralph.buckman@jhuapl.edu.



JEROME R. VETTER holds a B.S. degree in aeronautical engineering from St. Louis University (1960), an M.S. degree in applied physics from The Johns Hopkins University (1974), and has completed graduate studies in the Ph.D. program in astronomy at Georgetown University. He joined APL in 1974, is a member of APL's Principal Professional Staff, and is currently the Assistant Program Manager for Range Systems, as well as Project Manager of the High Frequency Ground Wave-Buoyant Cable Antenna project in SSD. His research interests included space geodesy and satellite navigation, applications of Kalman filtering, missile inertial navigation and guidance analysis, and radio and optical astronomy. His e-mail address is jerome.vetter@jhuapl.edu.

SECTION B. TACTICAL SYSTEMS

B1. Tomahawk Cruise Missile Test and Evaluation

David J. Carter

The considerable SSD test and evaluation expertise accumulated in support of strategic nuclear weapons systems has been successfully applied to several tactical systems. An excellent example of this effort is our participation in the Tomahawk Cruise Missile Operational Test Launch (OTL) Program. That program resulted from two complementary events in 1988: (1) the SSD Pershing II and Ground-Launch Cruise Missile theater nuclear forces evaluation programs were being terminated and subsequently withdrawn from Europe in response to the Intermediate-Range Nuclear Forces Treaty with the Soviet Union, and (2) the Tomahawk Cruise Missile Program Office was undergoing an extensive reexamination of its OTL Flight Test Program.

The Tomahawk OTL Program had been established by direction of the Chief of Naval Operations based on the concepts of the Joint Chiefs-of-Staff Commander-in-Chief evaluation requirement for the strategic ballistic missile programs. However, the OTL Program differed from the ballistic missile programs: it combined the primary objective of realistically testing the deployed force with the need to conduct periodic flight testing for system development and Fleet training objectives. The intent of the 1988 review of the OTL was to improve the overall effectiveness of the test program to meet these combined objectives.

In its role as the Technical Direction Agent (TDA) for Tomahawk, the APL Program Office in the Fleet Systems Department (now the Power Projection Systems Department) was asked to increase its role in the OTL Program in both the planning and analysis areas. The Program Office requested the support of SSD, and an interdepartmental effort—which continues today— was established whereby SSD would conduct the bulk of the Tomahawk test and evaluation effort within the TDA function.

The application of SSD's expertise to the Tomahawk Program encountered some challenges stemming mainly from the differences between the strategic and tactical force perspectives and organizational structures. However, the transition was generally smooth, due chiefly to the similarities between the evaluation requirements for the Tomahawk OTL Tactical Program and the strategic programs evaluated within SSD (Polaris, Poseidon, Trident, and Pershing).

> *In its role as the Technical Direction Agent for Tomahawk, the APL Program Office . . . requested the support of SSD, and an interdepartmental effort—which continues today—was established . . .*

Since 1989, the Tomahawk test and evaluation project has involved many tasks. Several recurring efforts include flight test planning, individual test preparations, and the system-level terminal accuracy performance assessment, which is presented annually to the Program Executive Officer for Cruise Missiles and operational mission planners. Nonrecurring evaluation tasks have also been undertaken, e.g., the validation of initial concepts for controlled time of flight to support coordinated strikes ("Strike Derby") and support of various system development options (including the recent Block IV upgrade effort).

One direct spin-off from the SSD strategic programs evaluation experience occurred in 1989 with the development of an at-sea test concept: a simulated launch exercise of the nuclear Tomahawk variant to monitor and improve system performance. This test, called TOMOPEX (Tomahawk Operational Exercise), was developed for the Commander, Submarine Force, U.S. Atlantic Fleet, and was used several times including once in conjunction with an OTL flight test, before transitioning to the Fleet for their own use.

The SSD effort in support of the OTL Program continues to evolve as the focus of the program changes. For example, the successful tactical use of Tomahawk in Desert Storm and subsequent strikes into Bosnia and Iraq have demonstrated the beneficial contribution of a continuing operational test program to the understanding and improvement of system capabilities. Current SSD Tomahawk test and evaluation efforts focus on refining the OTL Program to provide more tactically realistic results that incorporate a greater variety of test conditions and more realistic test scenarios. We expect this effort will continue to be a major component of SSD's support for Tomahawk.

THE AUTHOR

DAVID J. CARTER is a member of APL's Principal Professional Staff. He obtained a B.A. in engineering science in 1966 and an M.S. in engineering in 1968, both from Purdue University. Since joining APL in 1970, he has participated in several operational test and evaluation efforts including the Army Pershing, the Air Force Ground-Launched Cruise Missile, and currently the Navy Tomahawk Sea-Launched Cruise Missile programs. Mr. Carter served two tours at the APL European Field Office (EFO), first as the Assistant EFO Supervisor (1971–1972) in Heidelberg, West Germany, and later (1984–1986) as Supervisor of the APL Branch Office at Ramstein Air Base, Kaiserslautern, West Germany. He is currently the Manager of the SSD Tactical Systems Evaluation Project and the SSD/PPSD interdepartmental (Tomahawk) System Test and Evaluation Project. His e-mail address is david.carter@jhuapl.edu.

B2. Unmanned Aerial Vehicle Tactical Control System

Paul D. Worley

INTRODUCTION

Over the past decade, widespread military interest in unmanned aerial vehicles (UAVs) has spurred the development of many enhancements, including improved capabilities for surveillance and reconnaissance applications. To optimally use these new capabilities, UAVs must be placed in the direct control of forward area forces and must interface with command, control, communications, computer, and intelligence (C^4I) networks to disseminate critical information in a timely manner. The following goals have been established:

- Minimize the time required to provide useful and relevant battlefield information.
- Optimize the control of reconnaissance capabilities by putting the UAV directly in the hands of the intelligence user.
- Simplify operator training by providing a single common control and display system.

To meet these operational goals, the Program Executive Office for the Cruise Missile Project (PEO (CU))/Program Manager for Tactical Systems is developing a common UAV Tactical Control System (TCS) that will provide scalable C^3 capabilities for the Predator, Outrider, Pioneer, and future UAV systems while allowing receive and data dissemination capabilities for high-altitude UAVs. Figure B2-1 is a basic block diagram of the TCS system.

Interoperability between a UAV and a Navy submarine was first demonstrated in the SSN/UAV Predator Demonstration that occurred near San Clemente Island, California, in June 1996 (see the article by Vigliotti in this issue). The SSN/UAV test demonstrated the use of a joint UAV asset being "handed off" in flight to a forward-deployed SSN (USS *Chicago*) operating submerged at periscope depth, which subsequently used the Predator to support a Special Operations Force (SOF) mission. That demonstration was the culmination of an intense 10-month-long system development effort led by the Strategic Systems Department with sponsorship by the Office of Naval Intelligence, Chief of Naval Operations (N87), and

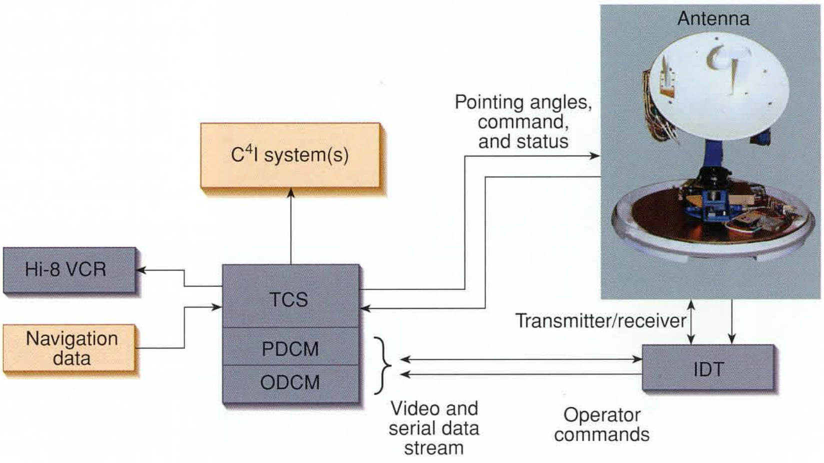


Figure B2-1. Block diagram of the unmanned aerial vehicle Tactical Control System (TCS). C^4I = command, control, communications, computer, and intelligence; IDT = Integrated Data Terminal; ODCM = Outrider Data Control Module; PDCM = Predator Data Control Module.

PEO(CU). The objectives of the development effort were to build a specialized prototype UAV control system to be installed on submarines and to demonstrate interoperability between the Predator UAV and the submarine's C^4I network.

The engineering testing performed with the SSN/UAV control system indicated robust range performance limited only by the radio horizon (170 nmi at a 21,000-ft altitude) and culminated with the use of the Predator UAV to support insertion of the SOF from the SSN onto San Clemente Island. This highly successful system demonstration led to a request for APL to participate in the engineering development of the common UAV TCS.

TCS DEVELOPMENT

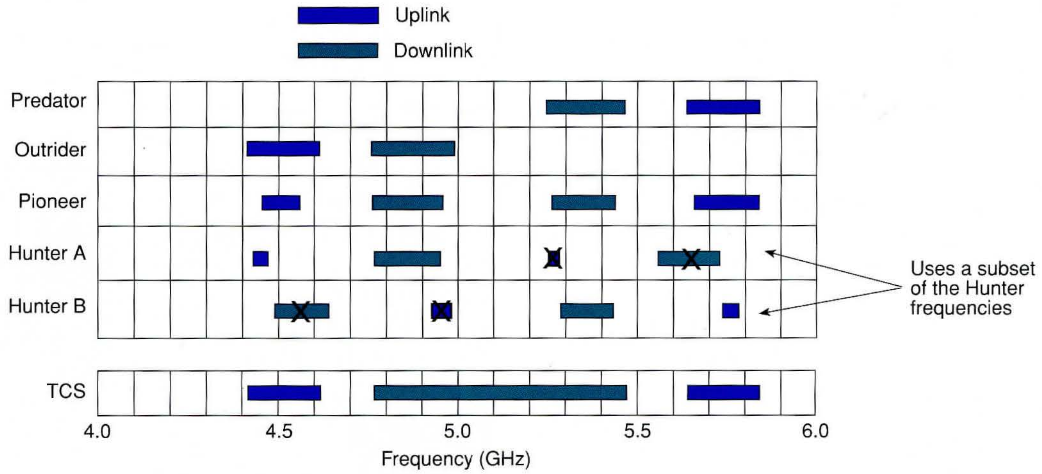
The UAV TCS Program at APL comprises an interdepartmental team with members from the Strategic Systems, Power Projection Systems, and Air Defense Systems Departments. This program is sponsored by PEO(CU). The engineering development work is primarily concentrated on the data link between the UAV and TCS. Along with the engineering development of this link, APL provides support for field demonstrations of the TCS.

The data link furnishes the critical connectivity function between the UAV and the ground station during the mission. It includes transmission of command and control signals from the ground station to the aircraft (uplink) and transmission of payload and aircraft status data from the aircraft to the ground station (downlink). The link may also provide receive (downlink only) access to UAV imagery and status for battlefield users such as SOF personnel.

During FY97, the TCS team developed the requirements and specification for a marine-environment version of the C-band line-of-sight antenna developed for the SSN/UAV demonstration. The new antenna derived from this specification was used successfully during testing with an Outrider UAV in February 1998. It included the same stabilized pedestal technology designed for the SSN antenna. The primary differences between the SSN antenna and the new marine-environment antenna are the requirements to provide a broader frequency band to cover two independent uplink frequency bands, a wider downlink band, and an omnidirectional capability.

The wider bandwidth provides support for multiple types of UAVs. Figure B2-2 illustrates the frequencies required by the data link to support various UAVs used by the military. The omnidirectional capability was needed to support launch and recovery requirements since rapid changes in azimuth and elevation during shipboard UAV launch and recovery are expected to be too fast for a directional antenna to follow. Because of these requirements, the new antenna needed a switching capability to select the appropriate uplink RF power amplifier, diplexer circuitry, and antenna type (e.g., directional or omnidirectional). Figure B2-3 is a block diagram of the antenna circuitry.

During FY98, the TCS team concentrated on extending this new antenna design to support mobile land-based TCS applications. The antenna requires a



Location	TCS frequencies (GHz)	
	Uplink	Downlink
Continental U.S.	4.40–4.62	4.75–5.00
Outside continental U.S.	5.25–5.47	5.62–5.85

Figure B2-2. Data link frequencies for unmanned aerial vehicles.

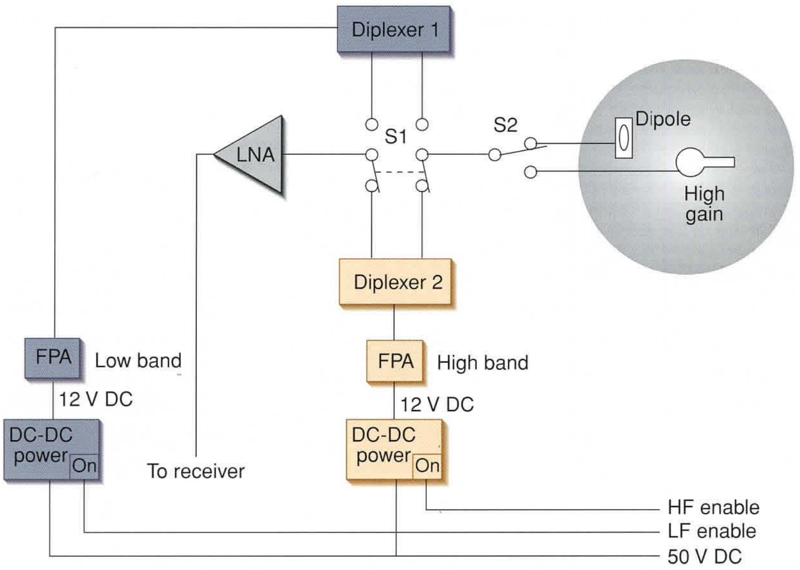


Figure B2-3. Functional block diagram of the UAV Tactical Control System antenna (FPA = final power amplifier, LNA = low noise amplifier).

minimal setup time to support the Army Tactical Operational Command Centers and high-mobility multipurpose wheeled vehicle (HMMWV) operations. In addition, the land-based version supports requirements of the Marine Corps for a mobile TCS. The RF and electronics capabilities of the land-based antenna duplicated the marine-environment antenna; however, the additional shock and vibration involved in moving and setup was analyzed to determine the requirements for the pedestal and packaging. This analysis concluded that the antenna/pedestal system developed for marine application is suitable for land-based use.

In conjunction with the antenna development, there is a requirement to control the antenna's pointing direction and functional setup. Antenna pointing and function control software was developed at APL during development of the SSN/UAV demonstration system. This software, which ran on a Sun SPARC 20 workstation, was integrated into the TCS core software. APL will continue to support this software integration through flight qualification testing, system integration testing, and flight certification testing for each applicable UAV.

TCS FIELD DEMONSTRATIONS

In early 1997, TCS participated in the Army Task Force XXI major field demonstration. The prototype TCS equipment, developed for the SSN/UAV interoperability test, was installed onto an Army HMMWV shelter (Fig. B2-4), and the stationary system was used to control Predator UAV pilot and payload functions. The equipment was interfaced to a Sun workstation that ran the TCS core software, which provided video capture capability and interface to several Army C^{4}I systems.

In addition to supporting installation and integration of the antenna and antenna control computer during this exercise, the Laboratory also provided flight certification testing at the El Mirage, California, flight test facility and subsequent demonstration support for Task Force XXI at Fort Irwin, California. The demonstration resulted in five successful Gnat 750 (Predator variant) UAV surveillance flights over Fort Irwin and was instrumental in the Task Force XXI Brigade's fighting the opposition Red Force to a declared standoff. The ability to successfully hold the Red Brigade (the Ft. Irwin Specialized Training Force) was considered a remarkable accomplishment. This exercise demonstrated the significant value of direct control of the UAV by forward area forces and the value of near–real-time dissemination of aerial imagery, both optical and infrared, to the forward area intelligence network.

By late 1997, the prototype TCS, including the APL antenna and antenna control system, was

Figure B2-4. APL-developed UAV Tactical Control System stabilized pedestal and antenna mounted on an Army high-mobility multipurpose wheeled vehicle.

installed on USS *Tarawa* (LHA-1) (Fig. B2-5) to support operations with the *Tarawa* Amphibious Assault Battle Group and the 11th Marine Expeditionary Unit during Fleet exercise (FLEETEX) 98-1M. These demonstration activities included installation of the antenna and control system onto a mobile test bed, flight certification at the El Mirage flight test facility, pierside testing, and at-sea data link testing using a manned light aircraft with a Predator data link installed. In addition to the TCS antenna control software, the APL multiple image coordinate extraction targeting concept software was installed on the antenna control computer for at-sea testing (see the article by Criss et al., this issue). FLEETEX 98-1M included flight operations near San Clemente Island and Camp Pendleton, California. These flights aided in aerial intelligence gathering, direct gunfire support, and battle damage assessment.

CONCLUSION

The use of UAVs to provide safe, reliable, and expendable battlefield surveillance is expected to grow significantly over the next decade. This growth will fuel the need for advanced surveillance capabilities. New aircraft concepts, such as the uninhabited combat aerial vehicle and miniature UAVs, are already on the drawing boards. SSD has demonstrated the broad-based systems engineering expertise required to develop reliable and versatile advanced unmanned vehicle systems, including advanced onboard sensor suites and data links.

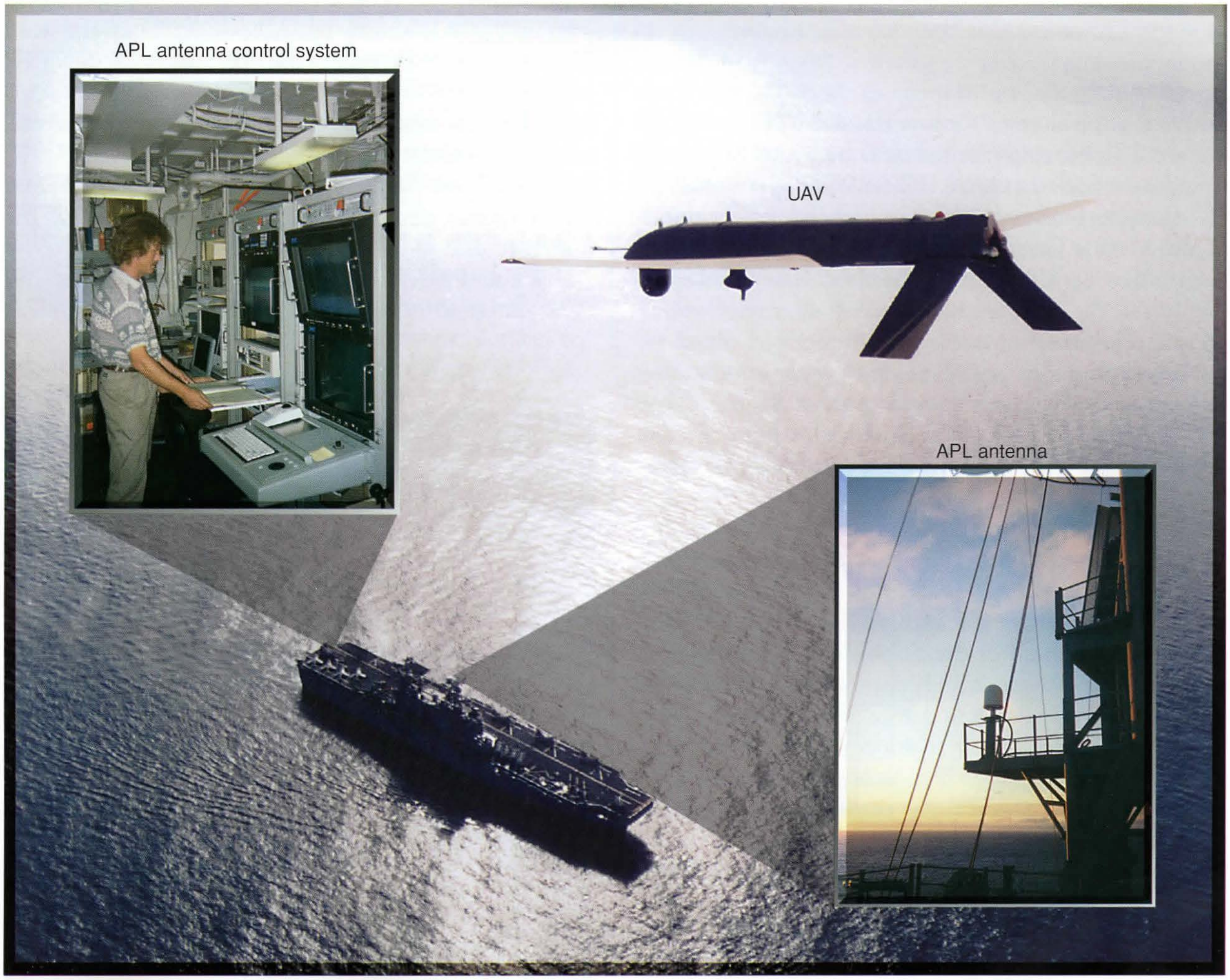


Figure B2-5. APL UAV Tactical Control System antenna installation onboard USS *Tarawa*.

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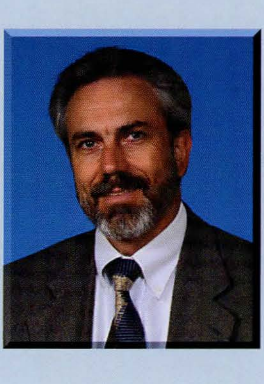

PAUL D. WORLEY received a B.S. in electrical engineering from Colorado State University in 1981 and an M.S. in electrical engineering from The Johns Hopkins University in 1991. He joined APL's Strategic Systems Department in 1981 and worked in the Sonar Evaluation Program. In 1985, Mr. Worley was appointed the first APL representative to the staff of Commander Submarine Development Squadron Twelve in Groton, CT. In 1990, Mr. Worley became a member of the SSD Signal Processing Group, where he worked on passive automation and SURTASS Twinline projects. He acted as Project Manager for the Twinline Sea Test Project and is currently the Program Manager for the UAV Tactical Control System. His e-mail address is paul.worley@jhuapl.edu.

B3. The Joint Countermine Advanced Concept Technology Demonstration

Ann G. Arnold

In 1995, the Deputy Under Secretary of Defense for Advanced Technology initiated a new and innovative aspect of DoD acquisition reform called Advanced Concept Technology Demonstrations (ACTDs). These demonstrations represent an attempt to accelerate the acquisition process and to encourage the acquisition community to cooperate earlier and more fully with the intended military user. The objective is to facilitate the evaluation of mature, advanced technologies that lead to an enhanced military operational capability or improved cost-effectiveness.

Significant participation by the warfighter in the planning and execution of the various demonstrations and exercises is a precept of the ACTD process. This approach provides a sound basis for investment decisions before commitment to system acquisition, fosters the development of new concepts of operation, and leaves behind a residual capability for the military user. An ACTD generally has a 3-year term and involves two large-scale demonstrations that focus on assessing the incremental military utility added by the new technology. When successful, ACTDs are intended to rapidly transfer the technology from the developer to the user.

The objective of the Joint Countermine ACTD (JCM ACTD), a "system-of-systems" demonstration, is seamless amphibious mine countermeasure operations from sea to land. The challenge is to demonstrate the capability to conduct such operations with major emphasis on clandestine reconnaissance and surveillance from space, air, surface, and subsurface platforms. Table B3-1 summarizes the 11 novel systems that constituted Demo II of the JCM ACTD. Other important elements were an enhanced C^4I (command, control, communications, computers, and intelligence) capability and a modeling/simulation component known as the Joint Countermine Operational Simulation.

In order to contrast capabilities and evaluate the potential military utility of the participating novel systems, an assessment strategy had to be developed. The extensive expertise of the Strategic Systems Department, accumulated from tests and evaluations of other programs, was leveraged to devise an analysis methodology for the JCM ACTD. Our responsibilities included developing a detailed analysis approach, defining data requirements and a data collection/analysis plan, participating in planning the ACTD scenarios, and producing Demo I and II scenario script playbooks.

The U.S. Atlantic Command, the operational sponsor for this ACTD, specified in their integrated assessment plan four critical operational issues (COIs) that form the basis for their evaluation of the improvement in countermine capability provided by the novel systems. From these COIs, system-level measures of effectiveness (MOEs) were developed. Figure B3-1 illustrates the bottom-up flow from the measures of performance of the countermine systems to the MOEs of each countermine operation, and finally to the COIs.

This initial architecture provided a structure for the development of specific countermine vignettes or subphase overlays to the exercise scenario that enabled demonstration of these countermine functions: mission planning, advanced force reconnaissance (covert and overt), clearance/breach, follow-on clearance, and route (chokepoint) breach/clearance. Development of each scenario overlay was intended to naturally motivate the use of the novel systems, provide the maximum opportunity to demonstrate the significant (i.e., measurable) utility of each novel system to the

Table B3-1. Novel systems participating in the Joint Countermine Advanced Concept Technology Demonstration.

System	Countermine function	Technology	Objectives
Littoral Remote Sensing	Clandestine surveillance and reconnaissance (Navy)	Infrared and visible imaging	Fuse and disseminate surveillance data from material assets and sensors Provide essential elements of information (minelaying activities; minefield and obstacle locations)
Advanced Sensors	Covert reconnaissance (Navy)	Toroidal volume search sonar Side-looking sonar Dual-frequency synthetic aperture sonar Electro-optic identification sensor Magnetic gradiometer	Clandestinely detect, classify, and identify mines from deep through shallow water
Near-Term Mine Reconnaissance System	Covert reconnaissance (Navy)	SSN-hosted recoverable unmanned underwater vehicle with multibeam active search sonars Side-scan classification sonar	Locate minefield gaps or lightly mined areas for approach lanes from sea echelon area to inner transport area and inner transport area to craft landing zone
Magic Lantern (Adaptation)	Overt reconnaissance (Navy)	Gated blue-green laser imaging	Detect minefields in shallow water, very shallow water, and on beach Find suitable craft landing zones
Airborne Standoff Minefield Detection System	Overt reconnaissance (Army)	Airborne infrared imaging	Detect minefields inland
Coastal Battlefield Reconnaissance Analysis	Overt reconnaissance (Marine Corps)	Multispectral optical sensor	Detect minefields on beach and inland Find suitable craft landing zones
Advanced Lightweight Influence Sweep System	Breaching (Navy)	Pulse-power–driven plasma discharge technology Superconducting magnetic technology	Sweep lanes from inner transport area to craft landing zone for follow-on forces
Explosive Neutralization (Advanced Technology Demonstration)	Breaching (Navy)	PC system with autonomous craft control Distributed explosive technology	Deploy explosive charges to neutralize surf zone mines Clear lanes for landing craft air-cushioned and amphibious assault vehicles
Power Blade (D7 bulldozer)	Breaching (congressional mandate)	Side-sweeping blade	Clear lanes for landing craft air-cushioned vehicles from high water mark to craft landing zone Perform follow-on clearance of beach and craft landing zones
Power Blade (D8 bulldozer)	Clearing (congressional mandate)	Side-sweeping blade	Perform follow-on clearance of beach and craft landing zones
Close-In Man Portable Mine Detector	Clearing (Army)	Ground-penetrating radar and infrared	Detect metallic and nonmetallic mines for various countermine situations

Note: Systems listed in sequential order of use.

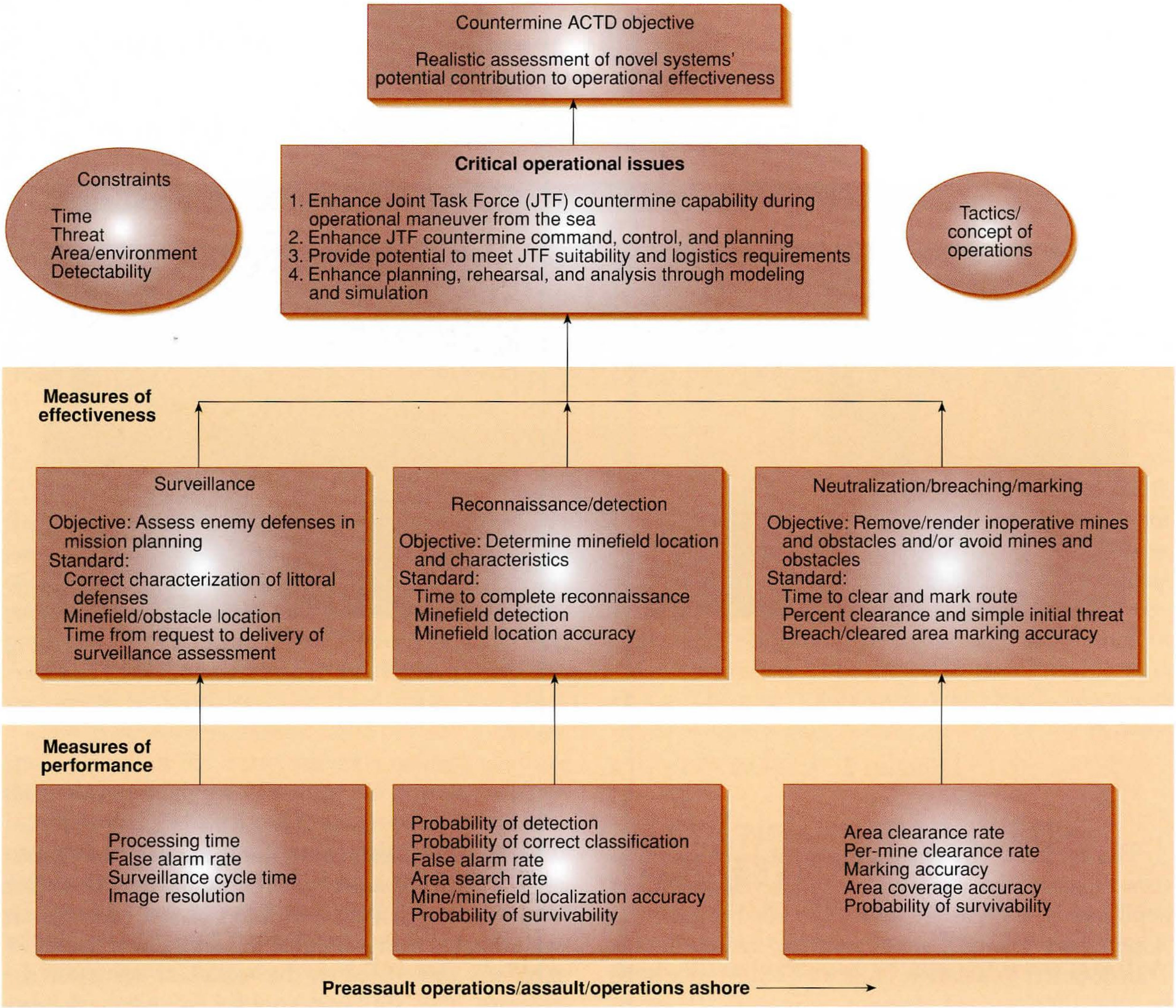

Figure B3-1. Joint Countermine Advanced Concept Technology Demonstration hierarchy of analysis measures developed to assess incremental military utility of participating novel countermine systems.

top-level MOEs and COIs, and present a significant but fair challenge to each novel system.

To ensure that adequate data were collected from each vignette during demonstrations so that meaningful evaluations of the participating systems and architectures could be made, SSD produced an analysis plan and associated data collection plan. These plans would ensure that a full reconstruction of the demonstration events (something that often goes undocumented in many major military exercises) would be available and that objective assessments could be made. The additional C^4I element noted previously provided the instrumentation needed to collect the quantitative data from each novel system.

JCM ACTD Demo I was conducted as part of Joint Task Force Exercise 97-3 at Camp Lejeune and Fort Bragg, North Carolina, in August and September 1997. Demo II was part of the U.N.-sanctioned, NATO-led, and Canadian-commanded exercise Maritime Combined Operations Training (MARCOT)/Unified Spirit (US) 1998 held in June 1998 in Stephenville, Newfoundland. During both demonstrations, APL staff from SSD and the Joint Warfare Analysis Department observed the operations, collected quantitative data, and solicited qualitative assessments from the operational users via structured interviews and questionnaires.

A "quicklook" report[1] and final report[2] were produced for Demo I, and the quicklook brief[3] for the recently completed Demo II was issued in July 1998. The results from Demo I have been widely disseminated throughout the defense community, and there is heightened interest in the MARCOT results to provide insights to guide significant countermine systems acquisition decisions. The analysis methodology developed by SSD and successfully applied to the JCM ACTD has enhanced the recognition of APL as an effective independent assessment agent.

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THE AUTHOR

ANN G. ARNOLD is a member of the APL Principal Professional Staff and currently the Program Manager for the Laboratory's efforts on the JCM ACTD. She received a B.S. in mathematics from the University of Maryland, College Park, in 1972 and joined APL later that year. Since then, she has contributed to several major test and evaluation programs executed by SSD. Mrs. Arnold also played a key role on the Government Evaluation Team for the Automated Surveillance Information Processing System. She serves as Supervisor of the Operations Assessment Section of the Undersea Systems Evaluation Group in SSD. Her e-mail address is ann.arnold@jhuapl.edu.

SECTION C. UNDERSEA SYSTEMS PROGRAMS

Douglas L. Geffert

The Strategic Systems Department Undersea Systems Program Area conducts systems development and performance analysis for submarine combat and mission support systems. Current programs include (1) the Trident Sonar Evaluation Program (TSEP) sponsored by the Director of Strategic Systems Programs (DIRSSP); (2) the Ocean Data Acquisition Program (ODAP) sponsored by the Office of Naval Intelligence (ONI); (3) the Navy Unmanned Undersea Vehicles (UUV) Program sponsored by the Program Executive Office for Undersea Warfare, UUV Programs Office; (4) the Seafloor Characterization and Mapping Project (SCAMP) sponsored by the Office of Naval Research (ONR) and the Lamont-Doherty Earth Observatory of Columbia University; and (5) the Ocean Engineering Program sponsored by several Navy agencies. In addition to these programs, SSD also supports the APL Submarine Technology Department in several areas related to undersea surveillance and submarine security.

TRIDENT SONAR EVALUATION PROGRAM

The Fleet Ballistic Missile (FBM) Sonar Evaluation Program (SEP) was established in the early 1970s by the Submarine Directorate in the Office of the Chief of Naval Operations (CNO) to support the independent assessment of sonar systems performance on the Polaris/Poseidon SSBN submarines (Fig. C1). The responsibility for execution of this program was subordinated by the CNO to the DIRSSP, and in 1975, APL was designated as the technical agent for this program. The SEP was extended to include the new Ohio class Trident SSBNs in 1983 under a management agreement between the Trident Acquisition Program Manager (PM-2), the CNO Strategic Submarine Branch (CNO OP-21), and DIRSSP. The scope and objectives of the TSEP were modified in 1992 and again in 1996 in response to the changing nature of the threat to the SSBN force (the FBM fleet consists of 18 Trident SSBNs).

Today, the fundamental guidance that shapes the TSEP technical objectives is reflected in the following passage from a Joint CNO N87/DIRSSP memo of understanding established in 1992 and reaffirmed in 1996:

> The TSEP contributes both technically and operationally to the security and effectiveness of the SSBN force. The TSEP shall focus on determination of sonar performance and effectiveness, and provide independent assessments of acoustic vulnerability.

The fundamental approach to addressing the sonar analysis requirements is to rely heavily on the use of instrumented acoustic data as a "ground truth" source from which assessments can be derived. Four Trident SSBNs have been equipped with SSD-developed

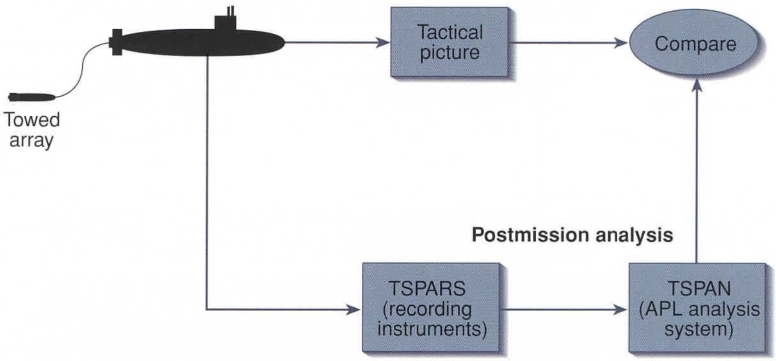


Figure C1. Functional flow for the APL Trident Sonar Evaluation Program.

Trident special-purpose acoustic recording system (TSPARS) instrumentation that continuously records the raw acoustic sensor data from all of the SSBN passive sonar acoustic sensors. These recorders are operated continuously whenever the SSBN is at sea on patrol. The data are collected after the patrol and are processed at APL using the Trident SEP Processor/Analyzer (TSPAN) processing and display system (see the article by South et al. in this issue).

The postpatrol processed data provide a ground truth picture of the entire acoustic contact environment surrounding the patrolling submarine. Comparison between real-time observations derived from the onboard displays by the sonar watchstanders and the ground truth picture produced from the TSPARS recorded data provides valuable feedback to the Fleet and the SSBN crew. An examination of the own-ship signature derived from the recorded acoustic data provides a continuous monitoring of ship "acoustic health." Both the TSPARS recording systems and the TSPAN processing and display facility are being upgraded to ensure that the capabilities required to support continuing assessments of SSBN sonar performance and acoustic health are sustained.

OCEAN DATA ACQUISITION PROGRAM

ODAP was established in 1976 by the Director of Naval Intelligence (CNO OP-009) in response to information developed by the SSBN Security Technology Program, sponsored by CNO OP-21. ODAP was tasked with developing nonacoustic antisubmarine warfare (ASW) sensor systems to investigate the tactical utility of nonacoustic ocean phenomenology. In the mid-1980s, the focus of ODAP was shifted to the development of special-purpose systems for use in various data collection applications. These systems have gone through several generations of development and refinement and have been used with considerable success.

More recently, ODAP has been tasked with developing a special variant of side-scan sonar to provide bathymetry mapping capability (Fig. C2). The first generation of this system was successfully deployed in 1996. The scope of ODAP tasking covers all aspects of systems development and operational support, including requirements definition, design, fabrication, integration with ship systems, installation, training of Navy personnel in operations and maintenance of special equipment, at-sea testing and grooming, mission support, and field service repair and refurbishment. ODAP continues to be tasked by the ONI, Maritime Systems Branch (ONI-7MS), with developing a variety of special-purpose sensor systems for use by Navy platforms.

NAVY UNMANNED UNDERSEA VEHICLES PROGRAM

The APL UUV Program was established in 1986 to support vehicle development efforts for both the Defense Advanced Research Projects Agency (DARPA)

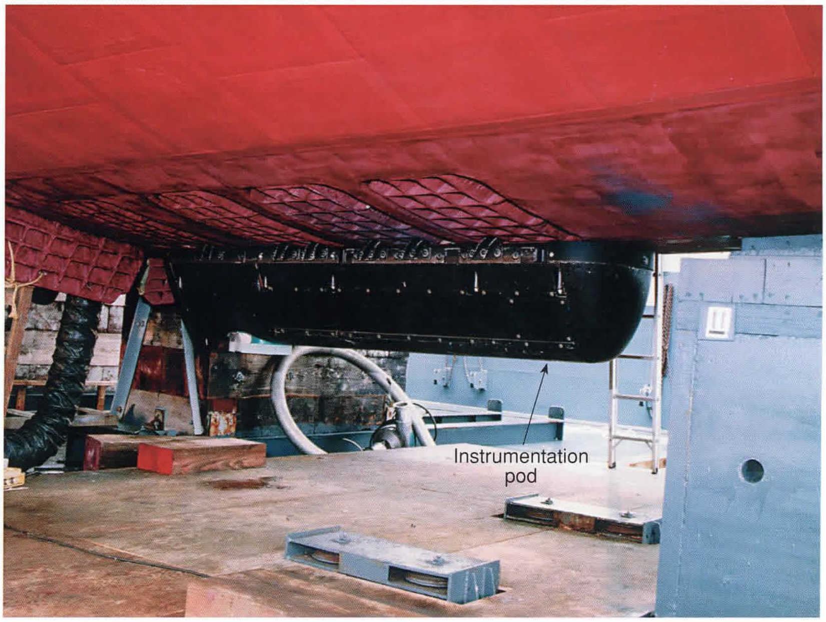


Figure C2. Ocean Data Acquisition Program external instrumentation pod affixed to the bottom of a submarine in drydock.

and the Navy. Begun initially as part of the APL Submarine Security Program within the Submarine Technology Department, the UUV Program transitioned to SSD in 1990 and currently is a multidepartmental effort. DARPA vehicles were tested extensively at sea from 1990 to 1996 on four projects: Tactical Acoustic System, Mine Search System, Submarine/UUV Laser Communications, and Autonomous Minehunting and Mapping Technologies. For the DARPA program, APL assisted in the formulation of system performance requirements, vehicle design concepts, test planning, test direction, and data analysis.

In 1991, the Navy's Program Office for Unmanned Undersea Vehicles (PMS-403) was established with oversight of ASW training targets and with the near-term goal of acquiring submarine-deployed UUVs. The Laboratory led development of a threshold baseline concept design for the Submarine Offboard Mine Search System (SOMSS), which examined the feasibility of meeting operational minehunting requirement thresholds in an affordable UUV design. APL staff also contributed to the Navy's UUV Master Plan, which replaced SOMSS with the Near-term Mine Reconnaissance System and the Long-term Mine Reconnaissance System (LMRS). APL led the Cost and Operational Effectiveness Analyses for LMRS and the Mk 30 Mod 2 ASW Training Target and continues to support the government in the technical evaluation of LMRS designs by industry competitors. APL plans to maintain a strong relationship with the UUV Program Office as the Navy begins to deploy these vehicles on a variety of missions.

SEAFLOOR CHARACTERIZATION AND MAPPING PROJECT

SCAMP is a submarine-mounted geophysical survey system for use under the Arctic ice sheet. The project was established at the Laboratory in 1997 to support the joint Navy/National Science Foundation (NSF) initiatives to explore the Arctic Ocean basin. Navy submarines are being used for annual unclassified Arctic scientific missions by a consortium that includes the Navy's ONR and Arctic Submarine Laboratory, NSF, the National Oceanographic and Atmospheric Administration, the U.S. Geological Survey, and the Lamont-Doherty Earth Observatory at Columbia University.

The APL task, which was contractually established through a grant from Columbia University, provided for the design, development, fabrication, and pier-side installation of two externally mounted instrumentation pods attached to the bottom of a Sturgeon class SSN submarine (Fig. C3). The smaller forward pod contains a high-resolution subbottom profiler (HRSP), and the larger, 16-ft-long aft pod contains a sidescan swath bathymetric sonar (SSBS). The HRSP is expected to penetrate the seafloor up to 100 m with a resolution in the tens of centimeters; the SSBS includes imagery over a 150° swath with good bathymetry over at least 130° in water depths of 2 to 3 km. Each pod is attached via a specially designed foundation mounted to studs welded on the hull; power and telemetry interfaces to the pods use existing SSN hull penetration fittings.

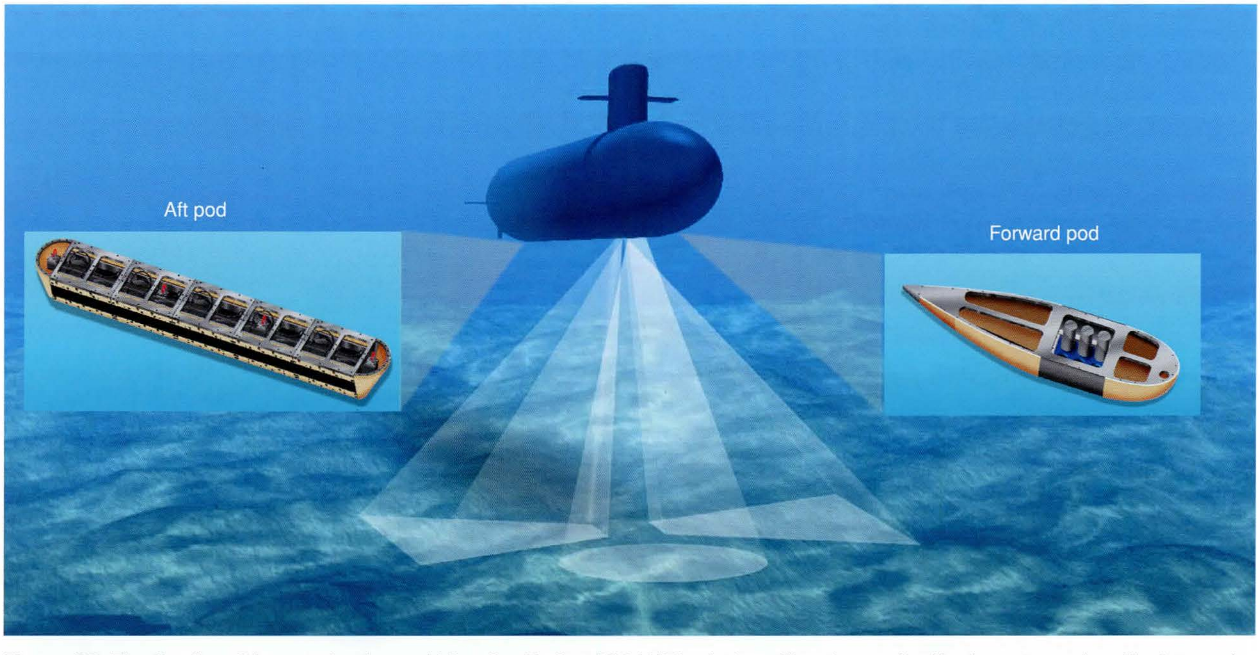


Figure C3. The Seafloor Characterization and Mapping Project (SCAMP) mission will gather seabed bathymetry and profile data under the Arctic Ocean ice sheet during a joint National Science Foundation/Navy science mission using USS *Hawkbill* (SSN-666). APL designed, built, and installed the SSN external instrumentation pods and attachments to carry the special SCAMP instrumentation.

The Navy has provided USS *Hawkbill* (SSN-666) as the platform for conducting the Arctic Ocean basin surveys with SCAMP. Special fixtures were designed by APL to allow the foundations and pods to be attached to the submarine without the need for drydocking (see Fig. C3). The SCAMP installation was successfully completed on the *Hawkbill* in April 1998 in preparation for the first of several Science Ice Exercise deployments to the Arctic. The SSD work performed within SCAMP has drawn heavily on the extensive experience gained in ODAP.

THE AUTHOR

DOUGLAS L. GEFFERT has a B.S. degree in mechanical engineering from Valparaiso University (1969) and is a member of APL's Principal Professional Staff. He joined APL in 1969 and worked in the Ship and Launcher Subsystems Group on a variety of Fleet Ballistic Missile tasks. In 1975, he was selected to be APL's Submarine Security Representative on the staff of the Commander, Submarine Force U.S. Atlantic Fleet, located in Norfolk, Virginia, and served in that assignment for 3 years. Upon returning to APL, Mr. Geffert served in numerous project and program management assignments, including Program Manager, Trident Sonar Evaluation Program, from 1988 until 1998. He is currently the Program Area Manager for Undersea Systems in the Strategic Systems Department. Mr. Geffert's professional interests include submarine operations, at-sea experimentation, systems development, performance assessment of complex undersea systems, and program and fiscal management. His e-mail address is douglas.geffert@jhuapl.edu.

SECTION D. BALLISTIC MISSILE DEFENSE

D1. Technical Support for the Ballistic Missile Defense Organization

Judson C. Brown and Gary R. Bartnick

INTRODUCTION

The Strategic Defense Initiative Organization (SDIO), established in 1983, recognized the need to create an entity that would provide broad, flexible science and engineering support focused principally on independent technical assessment and advice. After considering various approaches to obtaining such support for in-depth technical studies, SDIO initiated a consortium of federally funded research and development centers, national laboratories, and university affiliated research centers. The focus of SDIO was then "Phase One" deployment of an umbrella defense based on kinetic energy kill mechanisms ("Phase Two" would provide directed energy defensive systems in the 21st century). The newly formed consortium was therefore appropriately called the Phase One Engineering Team (POET).

The original members of POET, formed in November 1987, were the Aerospace Corporation, APL, the Charles Stark Draper Laboratory (CSDL), three Department of Energy units (Los Alamos, Livermore, and Sandia National Laboratories), the Institute for Defense Analyses, the Logistic Management Institute, MIT Lincoln Laboratory, the MITRE Corporation, and the Rand Corporation. All but CSDL remain today on POET, a name retained because of its recognition factor despite the loss of the Phase One concept when SDIO became the Ballistic Missile Defense Organization (BMDO).

SSD CONTRIBUTIONS

SSD has been an active member of the APL team supporting the POET consortium and, since 1994, has provided the leadership of that team. Our efforts have fallen into four general categories, which are outlined in the following paragraphs.

1. Major defense acquisition program (MDAP) interface
2. Specification and development of test and analysis tools
3. Technology investigations
4. System evaluation concepts

In support of the MDAP interface, SSD has assessed selected weapon system design features and has participated on source-selection technical advisory teams, test flight readiness review teams, and flight failure investigation teams. Specific areas of contribution have focused on

- Target development: participation on integrated product teams to review new candidate targets, target capabilities, and test range improvements needed to support BMDO programs
- Facility development: conduct of an independent review of the value and need for selected new hardware-in-the-loop test facilities
- Interoperability test tools: design review of the Theater Missile Defense System Exerciser, a major wargaming tool, and specification of exercises needed to assess BMDO interoperability issues
- Models and simulations: critique of major force-level models as well as independent verification and validation of other selected models
- Wargames: participation in the planning and execution of major wargames addressing BMDO battle management and command, control, communications, computers, and intelligence issues; adaptation of the APL Warfare Analysis Laboratory for appropriate exercises to address BMDO technical and operational issues

Technology investigations supported by POET have included phenomenological studies (e.g., target signatures) and analyses of countermeasures, technology insertions, and threats. SSD established the metrics for these investigations that allowed the merits of each option to be prioritized for consideration. POET is the primary source of independent technical support for the major system-level evaluations and assessments undertaken by BMDO.

SSD's heritage in evaluating large, complex weapons programs has resulted in many key contributions. These have included participation in major studies of technical and operational architectures (e.g., the Theater Missile Defense Capstone Cost and Operational Effectiveness Analysis), studies of international cooperative architectures, and value-added assessments of new battle management capabilities into the candidate system architecture. Most significantly, SSD has structured a full system-of-systems effectiveness evaluation framework called the APL System-of-Systems Effectiveness Tracking (ASSET) process, which is discussed in the next section.

THE ASSET APPROACH

SSD began an effort to define an independent systems evaluation concept, the Technical Independent Evaluation (TIE) Program, in 1992. Subsequently, BMDO shifted its focus from global protection against limited strikes to theater missile defense. As a result, the TIE Program was restructured and renamed ASSET (Fig. D1-1). The technical challenge facing the ASSET Program is to develop and implement a rigorous analytical methodology that allows for early performance predictions based on a limited amount of actual test data. Its purpose is to identify key performance drivers and techniques to mitigate potential deficiencies. In addition, it tracks the evolution of system capability as components proceed through their development cycles.

The ASSET methodology uses Bayesian statistical techniques at the individual weapon system level and stochastic analytical techniques at the force-on-force level. With the ASSET process, APL has been able to demonstrate these analytical techniques and their ability to produce relevant family-of-systems performance insights. Specifically, SSD focused on the

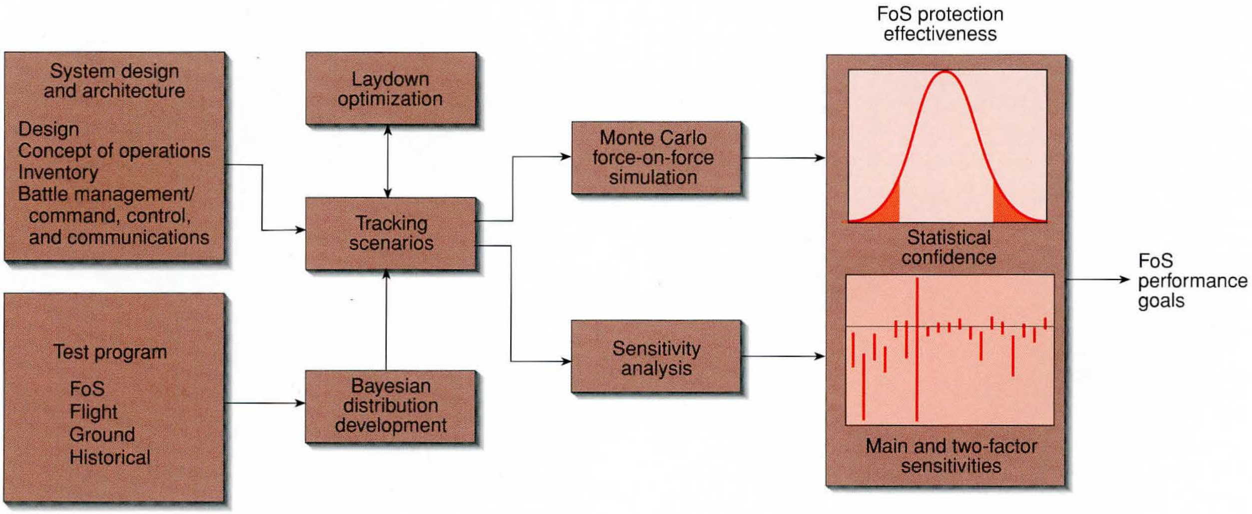
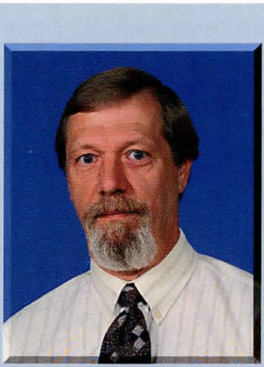


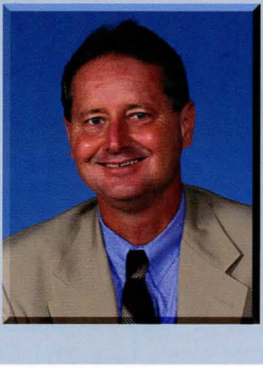
Figure D1-1. The ASSET process approach. The goals of this tracking methodology are to quantify the family-of-systems (FoS) performance, identify performance drivers, identify strategies to mitigate deficiencies, and collect feedback to asses the test program and FoS design.

projected initial deployment configuration of the theater missile defense family of systems. This configuration will have limited interceptor inventories, both upper and lower tiers. Optimizing defensive capabilities with such restricted inventories was a critical issue for both developers and users. With the ASSET analytical methodology, SSD was able to project alternative battle management and firing doctrine performance based on a conservative inventory. Efforts are currently under way to produce a second evaluation, which will extend the analyses to other theaters and expand the performance measures to include timing and system accuracy.

THE AUTHORS



JUDSON C. BROWN holds an M.S. degree in physics from the University of Virginia. He is a member of the APL Principal Professional Staff and is currently Supervisor of the SSD Defensive Weapons Section as well as the Assistant Program Manager of the BMDO POET and test and evaluation programs. Upon joining APL in 1975, he worked in the Pershing Evaluation Program, specializing in C^3 issues. Mr. Brown spent 4 years (1977–1981) at the APL European Field Office (EFO) in Heidelberg, West Germany, and served as the EFO Supervisor for 1 year. Following his return, he assumed responsibility for a Defense Nuclear Agency program to evaluate and enhance the survivability of the nuclear-capable land-mobile missile systems in Europe (Pershing, Lance, etc.). Mr. Brown also served as the Project Manager for the Joint Over-the-Horizon Targeting Program. Since 1992, his efforts have been devoted to support of BMDO, specializing in test and evaluation issues and C^4I. His e-mail address is judson.brown@jhuapl.edu.



GARY R. BARTNICK joined APL in 1964 while pursuing graduate studies in space science at Catholic University, having received a B.S. in physics from Siena College. He is currently the Program Manager for the BMDO POET Support Program and a member of APL's Principal Professional Staff. He served for 4 years as a member of the APL Polaris Division Fire-Control Group before becoming a charter member of the Pershing evaluation team. Mr. Bartnick spent 3 years as Assistant Supervisor of the APL European Field Office in Heidelberg, West Germany. He became the Assistant Manager for the APL Pershing Program in 1976 as well as the Chief Architect and Principal Analyst for the Pershing Survivability Program. Since 1989, Mr. Bartnick has been working with SDIO/BMDO concentrating on adapting APL's test and evaluation heritage to emerging missile defense system-of-systems concepts. His e-mail address is gary.bartnick@.jhuapl.edu.

SECTION E. CIVILIAN PROGRAMS

E1. Commercial Vehicle Operations Program

Kim E. Richeson

INTRODUCTION

The Commercial Vehicle Operations (CVO) Program began at APL in January 1994 under the sponsorship of the Federal Highway Administration (FHWA). CVO is one element of the FHWA's Intelligent Transportation Systems (ITS) Program, which is intended to increase roadway safety, reduce motorist delays and air pollution, and improve the overall productivity of CVO through the use of advanced technology. The FHWA is currently developing, testing, evaluating, and sponsoring the deployment of technologies to support traveler information services, traffic and transit management, driver security, and CVO. Furthermore, FHWA has developed a national ITS architecture that provides a framework for the development and deployment of these technologies. This framework includes the identification of standards for interfaces between systems.

The architectural framework and associated standards are essential to achieve North American interoperability and, thus, realize the full benefits of ITS. Under a series of tasks sponsored by the FHWA, APL, as system architect, developed the CVO information systems component of the national ITS architecture, now called the Commercial Vehicle Information Systems and Networks (CVISN, pronounced "see-vision"). APL's role includes providing technical support to the FHWA throughout the life cycle of the next generation of CVISN in multiple areas as follows.

- Develop guiding principles
- Develop concept of operations including
  - Key concepts
  - Scenarios
- Define the architecture including
  - Logical elements and interfaces
  - Standards requirements
- Develop a system design including
  - Physical elements and interfaces
  - Standards
- Develop the CVISN prototype to provide a technical demonstration and validation of the architecture
- Provide consultation to the CVISN pilot project in the form of workshops and advisory support
- Coordinate deployment through
  - Integration support
  - Interoperability testing
  - Training

The result of this support will be the pilot testing and deployment of government and carrier administrative/operations systems, government roadside systems, vehicle systems, and technical infrastructure systems.

CAPABILITIES

The CVISN Program has evolved to focus on three primary capability areas:

1. Safety information exchange
2. Credentials administration
3. Electronic screening

Safety Information Exchange

Safety information exchange provides carrier, vehicle, and driver safety information to roadside enforcement personnel and other authorized users. For several years, the FHWA has funded states through the Motor Carrier Safety Assessment Program to perform roadside audits of the safety processes of selected motor carriers and safety inspections of selected commercial vehicles. The Administration maintains a central Motor Carrier Management Information System (MCMIS) to support these tasks.

The safety information exchange capability is intended to provide automated collection of the results of vehicle inspections via a system called ASPEN (Fig. E1-1). Law enforcement personnel use this laptop or pen-based unit to enter the results of vehicle inspections as they are performed. This improves the accuracy of the entered data and enables officers to submit their reports immediately over a network, dial-up, or wireless cellular digital packet data link.

These inspection reports are relayed by the Safety and Fitness Electronic Records (SAFER) System back to existing state systems for some quality checks. The state systems in turn transmit the reports via SAFER to the FHWA's central MCMIS. In the past, data from this central system were available only via paper reports, but SAFER is now providing them online to safety analysts and law enforcement personnel.

The SAFER System receives an extract of subsets of MCMIS data, referred to as motor carrier, vehicle, and driver "snapshots." Snapshots are standardized sets of data that are used by automated systems, enforcement personnel, and administrative personnel to make safety and regulatory decisions. For example, the carrier snapshot contains the name and Department of Transportation identifier of the carrier, several statistical safety indicators, tax payment records, and other regulatory data items. SAFER snapshots are available to the general public via http://www.safersys.org/.

A key feature of the snapshot data is that changes are automatically distributed to users. Source systems recognize when a significant change has occurred and forward the data proactively to SAFER. SAFER uses the change notice to update snapshot data and forwards the data to update service subscribers. A state may subscribe to the carrier snapshots for all carriers registered to operate within it (an average of approximately 10,000 carriers per state).

A major expected benefit of the safety information exchange capability is to allow federal, state, and motor carrier personnel to improve the effectiveness of their safety programs by making more accurate and timely safety and related credentialing information accessible to them. In the past, it has typically taken 90 days or more for the results of an inspection report to be available to the enforcement community. Now, it can be done in less than 30 minutes. With better information, government agencies can focus limited resources on operators whose records indicate a safety history problem. Motor carriers can also use the data to help evaluate their own performance and target areas for improvement. APL's contribution to this area includes development of the overall architecture, electronic data interchange (EDI) standards for snapshot data exchange, and the SAFER System.

Credentials Administration

The central concept for this area is to allow motor carriers to apply for, pay for, and receive credentials electronically. Anyone who has had to title or register a personal vehicle can appreciate the magnitude of the

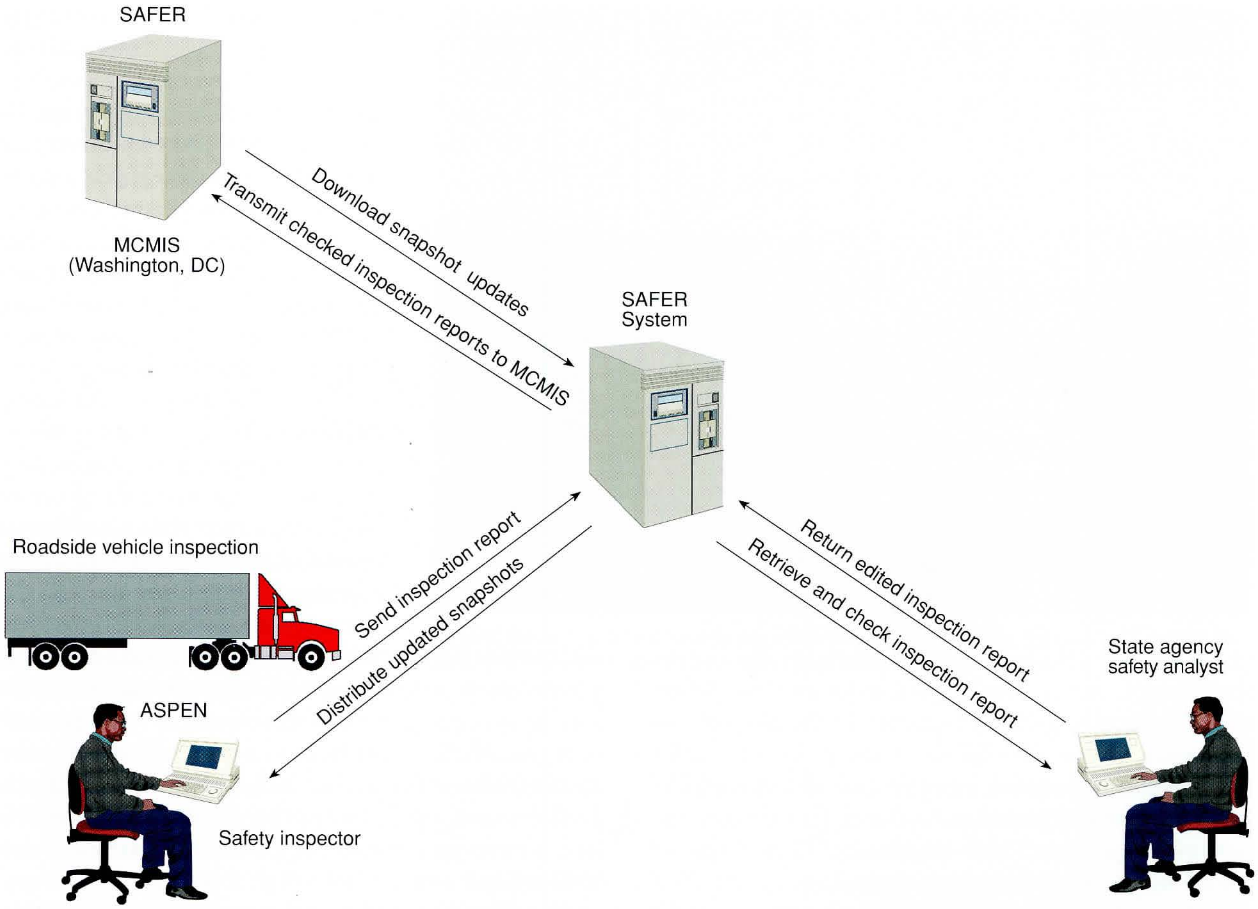


Figure E1-1. Safety inspection reports are entered into the ASPEN system and relayed electronically to state and federal systems (SAFER = Safety and Fitness Electronic Records System, MCMIS = Motor Carrier Management Information System).

commercial carrier's task, which may involve many hundreds of vehicles.

Most states have extensive information systems to process all the credentialing aspects of CVO. Motor carriers typically submit forms to register to operate as carriers, demonstrate possession of the required liability insurance, register and title vehicles, pay fuel taxes, apply for special oversize/overweight permits—the list goes on. The state processes these applications both manually and automatically. Often some sort of invoicing and payment is involved, which may be done electronically.

One goal of CVISN is to provide "end-to-end" automation of these credentialing processes, i.e., the electronic application, processing, fee collection, issuance, and distribution of CVO credentials, automation of tax filing and auditing, and the support of multistate information exchange and processing agreements. The carrier would use a software package called CAT (carrier automated transactions) to prepare applications. CAT would provide prompting and error checking to help improve the accuracy of the applications. (Some state agencies report that as many as 40% of the applications submitted manually contain some type of error, e.g., illegible entries, missing items, wrong identifiers, etc.) After completing the application, the carrier would transmit the form electronically to the state.

The information systems design used by each state will vary. A typical design is shown in Fig. E1-2. In this example, the state has a credentialing interface (CI) system that receives the applications and requests for all state agencies. The CI does some initial error checking and transaction archiving, and then routes the transaction to the appropriate state agency system to process the particular submission. For example, vehicle registration requests or renewals might go to the Department of Motor Vehicles, whereas fuel tax payments might go to the state Comptroller's Office. The actual processing of the form would be done in a system operated by a particular agency.

The CI system would typically be a "legacy" (previously existing) system that has been modified to include a new interface for accepting electronic transactions from the CI instead of accepting manual entries from state agency clerks. Part of the processing

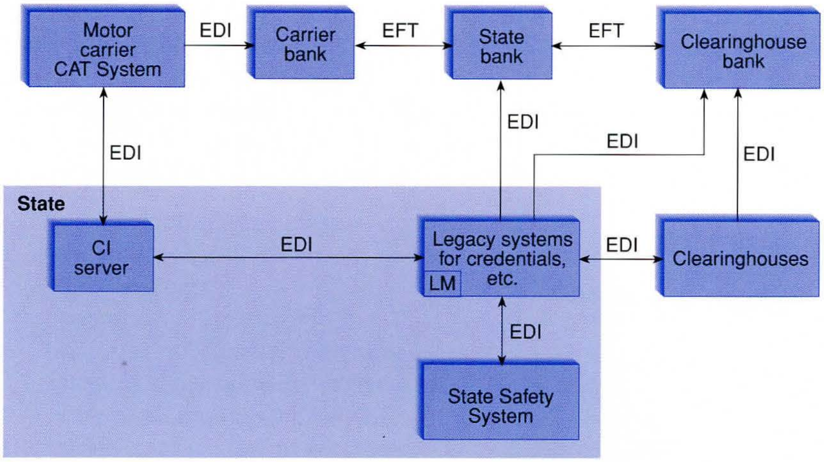


Figure E1-2. Standard electronic data interchange (EDI) transactions enable motor carriers to obtain credentials and states to process the applications and support base state agreements electronically (CAT = carrier automated transaction, EFT = electronic funds transfer, CI = credentialing interface, LM = legacy modification, LSI = legacy system interface).

might include checks to other systems to determine, for example, that a carrier who is requesting to register a vehicle is current on tax payments or that the vehicle is properly titled. The details of the processing differ for each transaction, but generally include error checking, cross checks with other databases, fee calculations, invoicing, payment, and issuance of some type of decal, sticker, plate, or paper document.

The goal of a CI system is to allow carriers to print their own paper documents. Decals and metal plates will need to be mailed to smaller carriers, although larger carriers will be able to maintain an inventory of these items at their sites, just as some states allow car and truck dealers to do today.

Another aspect of credentialing is sharing information among multiple states. States have evolved a number of "base-state agreements" over the years, including the International Registration Plan and International Fuel Tax Agreement. These agreements allow a carrier to designate a base state that it deals with, and that state in turn provides information and fee payments to other states. For example, a carrier may operate in Maryland and 10 other surrounding states. The carrier could choose to register its vehicles in Maryland as its base state. In completing the registration form (using CAT), the carrier would specify the expected percentage of allocation of each vehicle's mileage to each of the 10 states. The state of Maryland would process the data, calculate the fees based on the differing rates for each state, and exchange the necessary information and fee payments with each state. This is a great simplification for carriers who, until a decade ago, had to separately register and obtain license plates from each state for each vehicle that would operate in the state. A further improvement that CVISN is expected to achieve is the development of clearinghouses (e.g., International Registration Plan Clearinghouse, International Fuel Tax Agreement Clearinghouse) that will allow the states to exchange data and fees electronically rather than via paper reports as is done today.

The expected benefit resulting from the credentials administration capabilities is more efficient and responsive administrative processes for carriers and government agencies. The cost of compliance with regulations for both carriers and government agencies may be as high as $6B annually. Even a small percentage reduction in this figure can provide a high return on investment. In addition to the direct savings, automated processes will provide better information for measuring costs and effectiveness and will create a better environment for continual improvement of these processes and systems over time. APL's contributions to this area include the development of the overall architecture, the EDI standards for credentials data exchange, and a comprehensive set of requirements for the credentialing systems of Maryland and Virginia (Fig. E1-2).

In summary, standardized transactions with enable carriers to

- File for credentials from their offices and states
- Process applications automatically
- Exchange information electronically to support base-state agreements

These transactions will also support fee payments among payers, payees, and banks.

Electronic Screening

Most drivers have passed weigh stations on major highways. Signs direct trucks to pull into these stations to ensure that they are within federal and state regulations. Overweight trucks can cause excessive road wear. Most states limit trucks to an 80,000-lb maximum, with corresponding maximum weights on each axle. At a typical weigh station, trucks decelerate to a slow roll or stop at a static scale, which weighs each axle and total vehicle gross weight. This may take as little as 30 seconds or as much as 5 minutes, depending on traffic. But such delays can have a significant cost impact on some types of trucking operations. While the vehicle is slowing and stopped on the scale, law enforcement personnel check for the proper decals and any obvious safety problems. If they observe a problem, they ask the driver to pull into an inspection area at the site for a more thorough examination.

Another aspect of ITS/CVO is to put weigh-in-motion scales in the main highway (or at the beginning of the weigh station ramp) to measure the weight of trucks while they are moving at highway (or ramp) speeds. The trucks would also be equipped with dedicated short-range communication (DSRC) transponders, which can be interrogated by roadside readers as the vehicle goes over the scale. This reader would obtain identifying information from the transponder equivalent to the license plate number. A roadside operations computer in the weigh station would use this identifier to check information about the vehicle and the associated carrier using the snapshot information provided by SAFER. The computer would check the safety rating of the vehicle and carrier as well as proper vehicle registration, current tax obligations, and other recent problems. If the weight and other checks are good, the DSRC reader will send back a message to the transponder to that effect. The transponder, which would be mounted on the dashboard, then would display a green indicator to signify that the driver may proceed or a red indicator to signify that the truck is to pull into the scale. Enforcement personnel would be able to set up the computer to pull in a certain number of vehicles for random safety inspections, just as they do today with manual systems.

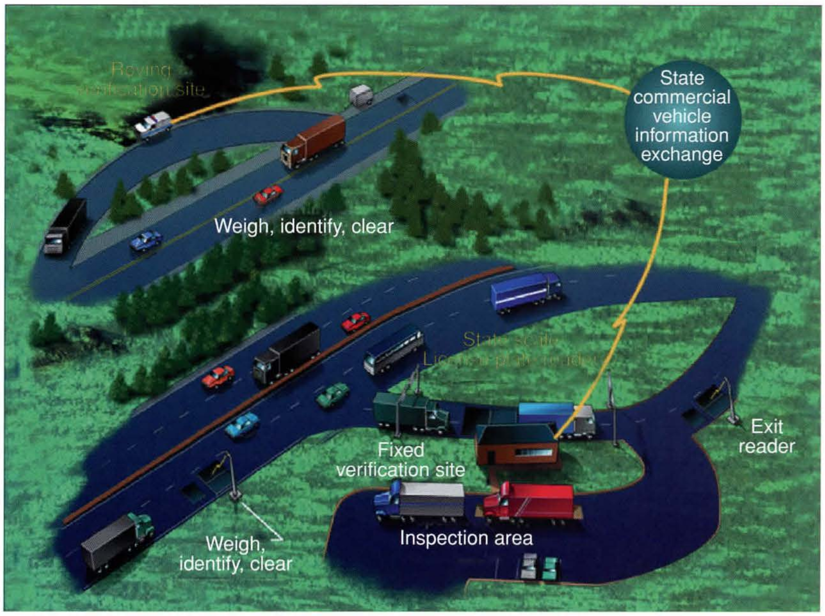


Figure E1-3. Electronic screening allows the weight, safety history, and credentials history of the carrier to be checked without stopping the vehicle.

These electronic screening capabilities will allow state safety enforcement units to focus on high-risk operators and will provide safe and legal carriers more efficient movement of freight (Fig. E1-3). APL is developing the overall architecture and DSRC standards, serving as the system integrator for the Stephens City, Virginia, weigh station, and developing the roadside operations computer software for Stephens City. The electronic screening capability may be implemented at either fixed or mobile sites. APL developed a mobile version of an electronic screening system called the Roving Vehicle Verification System (ROVER) that has been used to demonstrate the concept to state and federal officials. Virginia used the ROVER as a model for a similar mobile unit called NOMAD that they have deployed this year.

DEPLOYMENT

The CVISN Program is proceeding in five major steps.

1. Develop the management (plans) and technical (architecture) frameworks necessary to coordinate the subsequent phases (1994–1996)
2. Prototype the technology in an integrated way in two states to demonstrate operational concepts and validate requirements (1996–1999)
3. Pilot the approach in eight additional states (California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, Oregon, Washington) before proceeding to widespread deployment (1996–2000)
4. Expand the effort from the pilot states to all interested states (1999–2005)
5. Operate and maintain deployed systems (2000+)

Step 4 should be a smooth expansion, since each expansion state will be coordinating with a pilot state in the same region. By this time the technology, concepts, costs, and benefits should be well understood and documented. Deployment should be straightforward with little risk.

Throughout this process, the FHWA is focusing on "mainstreaming," a term which refers to the organizational aspects of moving ITS/CVO services beyond the concept development phase and into operation. As part of mainstreaming, certain organizational strategies will be implemented to support the technical activities. The ITS/CVO Program will develop policies, plans, programs, and projects at the state, regional, and national levels: at the state level because the states have the power and responsibility for building and maintaining highways and for taxing and regulating the motor carriers that use them; at the regional level because most trucks operate at the regional level; and at the national level because of the need to ensure uniformity of services for interregional and international motor carriers. APL will provide technical support to these programs and projects as required to make certain that lessons learned from the prototype and pilot efforts are brought forward to the CVO community.

SUMMARY

The ITS/CVO Program offers an exciting opportunity for APL to contribute to a significant national problem in a nondefense arena. The problem has many interesting technical aspects including system architecture, standards development, information systems development, communications, and technical program management. It also includes equally challenging institutional problems in bringing together the federal government, state governments, motor carriers, and technology vendors in a cooperative effort to reach policy agreements and develop interoperable systems.

The program draws upon APL's expertise in systems engineering and program management derived from our defense activities. We anticipate that the technologies currently being developed under this program will be widely deployed among the majority of states and many motor carriers over the next 5 to 10 years. The expected benefits in safety, savings, and simplicity will more than justify the investments made in the development of these capabilities.

The first areas of focus—safety information exchange, credentials administration, and electronic screening—are only the first in a series of possible improvements. Future FHWA efforts will continue to enhance and improve these capabilities as well as develop others in the areas of onboard vehicle monitoring and control and intermodal freight transportation. Current information about the APL CVISN Program can be found at the program's Web site (http://www.jhuapl.edu/cvisn/).

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THE AUTHOR

KIM E. RICHESON received a B.S. in engineering science from Purdue University in 1968, and an M.S. in computer science from The Johns Hopkins University in 1975. He has 30 years of experience in developing management information, business, and tactical defense systems and software. Mr. Richeson was a part-time instructor in the Technical Management Program at the JHU G.W.C. Whiting School of Engineering from 1990 to 1993. His work assignments have included both management and systems engineering responsibilities in applications areas for commercial vehicle operations, management and business information systems, computer facility development, computer peripheral emulators, shipboard combat simulators, tactical simulations, and radar detection and tracking systems. Mr. Richeson is currently the Manager for the APL CVISN Program. His e-mail address is kim.richeson@jhuapl.edu.