Information Management: The Advanced Processor Build (Tactical)

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APL's National Security Technology Department has contributed significantly to the advancement of information management systems throughout its 25-year history. Today, the department is on the leading edge of several key programs involving these systems, and has taken a prominent part in leadership, design, development, and end-to-end testing. APL's role on one such system, the Advanced Processor Build (Tactical), and its associated Acoustic Rapid Commercial Off-the-Shelf Insertion, has enabled the Navy to realize a truly revolutionary approach to combat information systems design, development, testing, and deployment.

INTRODUCTION

Information management, an extremely wide-ranging area of interest, is generally accepted as encompassing the collection, storage, analysis, synthesis, and delivery of data, information, and knowledge. Information management systems have existed in certain forms for decades, but are just now becoming advanced enough to perform tasks as powerful and diverse as reliably reducing manpower aboard ships through both automation of human tasks and enabling the operator to make tactical decisions in a more timely and accurate manner. A variety of information management systems must be available for sharing, storing, and distributing the information and knowledge that emerge from military operations, ranging in complexity from those required to assist operator entry of data to those capable of autonomous control over widely distributed and disparate sensors on the Global Sensor Grid. Autonomous systems, using intelligent agents (i.e., software entities that act on behalf of another using reasoning and that are capable of learning), can mine or extract large quantities of precise information from vast data warehouses with minimal human direction.

Many classes of information management systems exist with varying levels of complexity. Decision support generally includes decision aid, data warehousing and storage, collaboration, and knowledge management systems. More complex systems include tactical decision aids (TDAs), expert systems, and advanced intelligent systems (e.g., neural networks).

APL's National Security Technology Department (NSTD) has been on the leading edge of information management systems throughout its 25-year history. Examples of virtually every type of system mentioned above include the Integrated Submarine Stealth Information Processing System, Tactical Scene Operator/ Associate, Integrated Vulnerability Management, Total

Ship Monitoring, Electronic Surveillance Measure Vulnerability Server, Tactical Planning Associate, Automated Mission Planner and Executor, Stealth Planning Associate, and Miniature Mode Estimation Capability.

One of the current information management programs in which NSTD is involved is the Acoustic Rapid Commercial Off-the-Shelf Insertion (ARCI) and its annual software refresh cycle, the Advanced Processor Build (APB), sponsored by NAVSEA's Advanced Systems Technology Office (ASTO). The focus of this article is the Advanced Processor Build (Tactical) (APB(T)) process and the associated Advanced Combat Systems program in NSTD's Applied Maritime Technology Branch.

ADVANCED PROCESSOR BUILD (TACTICAL)

The APB(T) program evolved as the natural offshoot of the Advanced Processor Build (Acoustic) program, which began several years ago. Each APB is titled by the year of planned delivery for Fleet introduction into the designated system (e.g., APB-02 delivered to the integration agent in 2002). The sonar (acoustic) APB is referred to as APB(A), and the complementary Combat Control System (Tactical) APB is referred to as APB(T). Sonar TDAs are delivered to the Fleet via an APB(A); all tactical control information management TDAs and functionality are delivered via an APB(T).

The specific goal of APB(T)-01 was to improve the effectiveness of both the Commanding Officer and the Officer of the Deck (OOD) in managing an important tactical control issue: the "close encounter." The reduced detection footprint of submarines, added to the increasingly difficult recognition of submarine-generated noise ("exploitables"), has led to increased potentials for close encounters. APB(T)-01 focused on close encounter management improvements, including new and upgraded tools for correlation, localization, and targeting of tactical contacts—all vital aspects of contact coordination. APB(T)-02 concentrates specifically on the development of tactical information (e.g., automated rapid target motion analysis, localization, and targeting techniques) during close encounters and high contact density situations.

One factor enabling the APB(T) process is the use of commercial off-the-shelf (COTS) products and the Open Systems Architecture (OSA) within the tactical combat systems. COTS and OSA have both allowed advanced development to be accomplished on a target hardware and software footprint that is readily upgradeable and supportable. This factor, coupled with the use of a proven four-step APB transition process, allows a more rapid introduction of advanced capabilities to meet the Fleet's most urgent needs. ASTO is responsible for the development and testing of acoustic and tactical APBs, leading to improvements in sonar performance and tactical control information management. APBs are designed for implementation through the technology insertion schedule of the Acquisition Program Office.

Notional processing improvements are subjected to evaluation or assessment at four points (steps) in the process cycle to establish the maturity of the technology, risk of implementation, and value added to overall tactical system performance.

Step 1 (algorithm survey) is a survey of promising algorithms from the R&D community, including 6.2 and 6.3 activities, sponsored by organizations such as the Office of Naval Research, Defense Advanced Research Projects Agency, Industry Independent Research and Development efforts, Broad Agency Announcements, and related Navy programs such as the Submarine Security Program and the Integrated Undersea Surveillance System. The goal of Step 1 is to consider algorithms developed in other Navy-related programs and determine their tactical importance, maturity, expected performance, and computational resource requirement.

Step 2 (algorithm testing) is a test of relatively mature algorithms that promise to provide performance improvements to the Fleet. The test uses common data sets and common metrics developed by a working group of technical principals in conjunction with the developers and Fleet representatives. Based on real-world data sets collected from U.S. submarine exercises and provided by the Office of Naval Intelligence, this testing provides a projection of algorithm performance using ocean noise and target signatures of interest. Experience has shown that testing on synthetic data does little to uncover problems or reliably project performance for sonar algorithms in Fleet use. The APB Step 2 process is unique in that developers submit algorithms for testing with the expectation of useful feedback from the testing process. Algorithm promotion to Step 3 is determined by the cognizant peer review based on acceptable performance of the algorithm in Step 2 testing.

Step 3 (integrated testing) involves end-to-end testing of the integrated APB(T) system using stimulators and recorded real-world mission and exercise data to enable full system assessment of the improvements. While the use of stimulators is necessary to verify certain implementation features and to increase the diversity of available scenarios, the focus is on the use of real-world data since stimulators are not as good at stressing the system (e.g., noise, signal dropouts, etc.). The Step 3 test provides an opportunity to independently test the APB for compliance with performance requirements as well as fidelity with Step 2 performance results. It also serves to introduce Fleet representatives to the new features and to enable Fleet feedback. Any identified issues resulting from Step 3 testing are then forwarded to the

integration agent for resolution prior to at-sea testing. Independent testing of the APB product is a critical step in the build-test-build process. It ensures readiness for at-sea testing and provides confidence to the community contributors that their ideas have been implemented properly. Figure 1 shows an architecture configuration used to support APB(T)-01 Step 3 testing.

Step 4 (at-sea testing) is the most important phase of testing the algorithms prior to inclusion in the baseline system and yields information on how the Fleet team interacts with the APB in time for enhancement or corrective action. The test provides the opportunity to verify APB algorithmic performance and collect calibrated data for future use. The test team is responsible for the evaluation and assessment of test results as well as interpretation of algorithm and system-level performance. (*The at-sea test is not intended to serve as system certification. System certification is accomplished by the cognizant program office via separate testing after full integration of the APB into the baseline system.*)

Following Step 4 testing, the APB is delivered to the program office for integration into the baseline system. To assist in the successful transition of APB improvements, a Systems Engineering Working Group is established during Step 3 (and continues through Step 4). This group ensures that issues related to APB integration are resolved as early as possible in the development cycle and that systems-level requirements are factored into the APB product. In Step 3, the group also initiates development of any required program office documentation, such as specifications and change proposals, to ensure that the baseline system can readily incorporate the APB product.

The goal of APB(T) and APB(A) is to compress the time from ability to detect a contact to the time the OOD can take appropriate action. By reducing the time to classify a contact or conduct a maneuver, the system increases the time the OOD has to take evasive action. The APB process addresses this goal and attempts to provide significant, quantifiable enhancements.

ADVANCED COMBAT SYSTEMS PROJECTS

The Advanced Combat Systems program at APL is composed of several projects, each emphasizing a different major thrust. Working primarily for the ASTO sponsor, these projects focus on the development and testing of advanced submarine combat systems important to the Navy.

Test, Evaluation, and Assessment

The basis of the Test, Evaluation, and Assessment project is APL's trusted agent status in submarine combat system test and evaluation. As one of the lead laboratories in this area, the Laboratory's Advanced Combat Systems program leads the way to assist ASTO in identifying and researching APB candidates during the Step 1 process. In addition, APL serves on a multi-organizational Test, Evaluation, and Assessment Support Group that determines the extent of testing required. Once chosen to become part of the fiscal year APB, the group works with the algorithm developers to conduct engineering testing and then independently evaluates the respective product during Step 2. Tests such as those required to stress the system as it would be stressed at sea
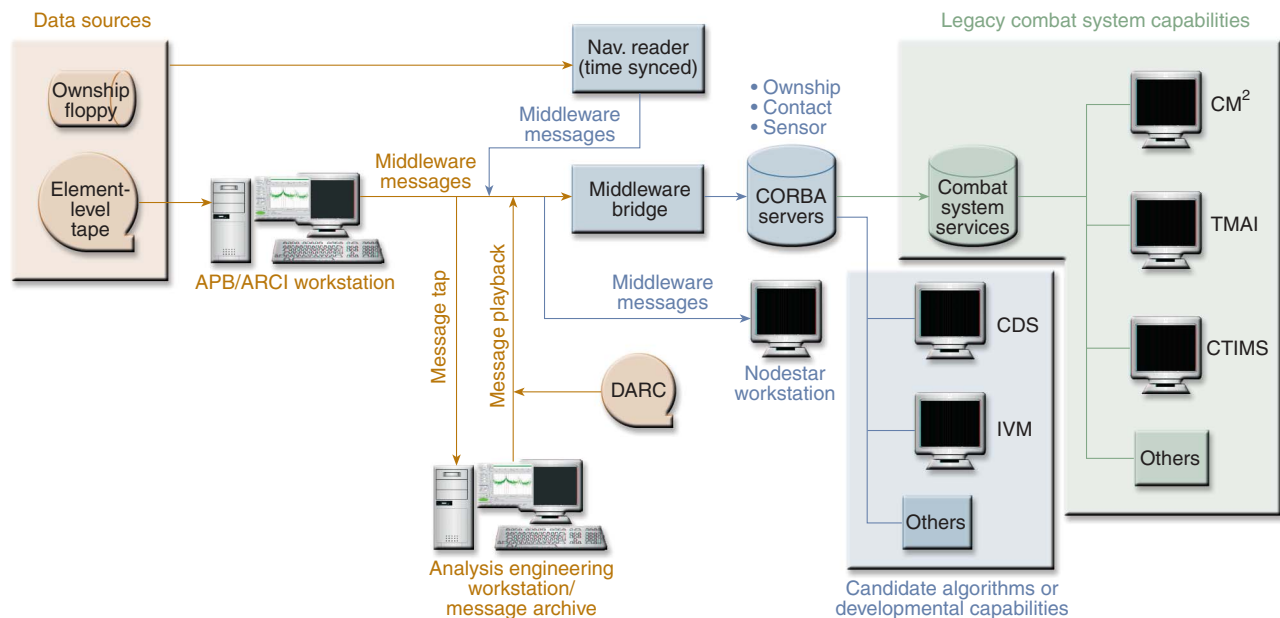

Figure 1. End-to-end processing facility. (CDS = contact data server, CM^2 = contact management engine, CTIMS = Command Tactical Information Management System, DARC = Data Acquisition and Replay Capability, IVM = Integrated Vulnerability Management, and TMAI = Target Motion Analysis Improvements.)

use data sources including available (previously recorded) at-sea data, simulated data if required, and output data and associated data evaluation. The testing specifically accomplishes the following:

- Verification, through the use of at-sea data and in some cases simulated data, that the APB(T) algorithms and information displayed are correctly implemented and that implementation problems do not degrade algorithm performance or interfere with testing. In addition, this testing verifies the correct display of ownship and sensor information, verifies the correct display of algorithm outputs, and compares APB(T) algorithm outputs with the results of baseline testing conducted during Step 2.
- Measurement of the performance of the APB(T) algorithms using recorded real-world data. To accomplish this performance measurement, the testing verifies that this APB(T) implementation meets or exceeds the performance of the previous (during sea tests) APB(T) through the use of recorded data from Step 4 (at-sea test) as the system input. In addition it measures the algorithm outputs for the purpose of comparison with each other and legacy algorithm performance, and measures the contribution to operator/OOD effectiveness of the new algorithms compared with legacy system capabilities through the use of operability testing.
- Verification that the system meets the documented operator–machine interface requirements of the Tactical CONOPS Support Group
- Establishment of baseline performance data for comparison with future APB implementations

A key objective of the analysis is to ascertain whether the APB(T) system is providing improved performance over the baseline system. "Baseline" is defined here as the legacy system to the extent that real-world data can be played through it. Because of this limitation, for legacy purposes, the testing focuses on modern implementations of legacy algorithms, which are indicative of the most advanced capability available to most of the Fleet (CCS Mk 2 Block IC capabilities). Metrics include the accuracy of the solution, distance from the true solution, correct representation of uncertainty, and solution quality as it relates to the decision-maker's actions.

Finally, the analysis attempts to determine whether the APB(T) system is performing as predicted. Comparisons are made between measured performance (i.e., measured contact range and bearing) and predicted performance against known information (i.e., actual contact position) to further assess the quality of the algorithm implementation, provide feedback to the Step 3 process, and support improved performance prediction methodologies.

Integrated Vulnerability Management

One system that will transition to the APB process this year is the Integrated Vulnerability Management (IVM) System. IVM provides a continuous indication of a submarine's vulnerability from the radar detection of exposed masts, intercept of extremely high frequency communications, magnetic anomaly detection, daytime and nighttime passive optics, buoyant cable array, and lidar.

With acoustic information coming from the sonar TDA, IVM provides a geosituational display of ownship and contact information, including detection and counterdetection ranges. It also supports mission planning and basic "what if" investigations. IVM provides the ability to modify contact, emitter, ownship, and environmental parameters to more accurately render the tactical scene.

Imaging

One of the greatest needs in the submarine force today is the ability to optimize the use of the information available to the OOD as he looks out of the periscope. The periscope currently configured is a small visual window that is useful normally only to the OOD and perhaps a few others. The data flow out of the sensor is far behind that of other onboard sensors such as sonar, electronic surveillance measures, and radar. The Imaging Project attempts to increase this data flow by working with other organizations to capture the available information in the form of still and panoramic pictures; to detect automatically, and with operator assistance, contacts that may exist; and to provide combat system–ready information on each contact such as bearing, bearing rate, and classification.

The Imaging Project provides improved periscope image quality through median filtering for noise reduction, histogram equalization if needed, and automatic cropping of invalid regions. Some of the technical challenges have included automatic slope detection and removal, automatic detection of the horizon through Viterbi-based directed optimal path search, vessel detection that will be attached to the horizon and above it by using maximum phase congruency for edge detection, local entropy methods, and region growing techniques for individual pixel classification. The project further attempts to classify vessels as one of n discrete classes, based on a database lookup for average class height, and then to determine an estimated range and angle of the bow based on that classification.

Option Reduction

A major thrust for APB-02 is contact management in a high contact density environment, e.g., a busy port, a strait, or other contained areas of high shipping density and potentially limited maneuverability. The purpose of

the Option Reduction Project is to give supervisory-level watch standers the ability to quickly visualize the best options in such an environment for achieving multiple goals (e.g., ownship movement, contact avoidance, land avoidance, etc.) based on the current tactical and shipping density situation within the operational and navigational constraints. The OOD's goals—avoiding a close approach, maintaining the planned movement schedule, avoiding detection—and his options (constraints)—the ability to change course, speed, depth, acceleration, turn rate—are added to the predefined constraints such as counterdetection threat, navigational hazards, schedule, and time. The approach is then to engage automated constraint-based reasoning algorithms operating under uncertainty (range errors, bearing errors, etc.) to assist in highlighting possible course/speed combinations for ownship that maximize the probability of achieving the desired goals. The Option Reduction Project also provides visualization tools to support a rapid and intuitive grasp of option constraints.

Testbed

Overview

In support of APB(T), APL, under ASTO funding, established a development testbed in the Tactical Research and Evaluation Center to support the evaluation of advanced submarine combat control system tools and capabilities. The initial purpose of the facility is to enable end-to-end processing of at-sea sensor data to stimulate the combat control system for test and evaluation of various APB(T) algorithms and technologies. As an independent tester and evaluator, APL conducts the crucial test and analysis activities and provides recommendations to its sponsor. The test facility also serves as a development and pre-integration facility to determine the readiness of those systems for testing at sea.

Briefly, the testbed

- Provides at-sea data playback of APB data sets, including acoustic and nonacoustic data
- Supports test and development of decision aids and workload management tools
- Develops interfaces to legacy systems (e.g., CORBA and other middleware interfaces to legacy combat systems)
- Develops tools to support data analysis
- Establishes connectivity on the Submarine Warfare System Wide-Area Network to support wide-area test and integration
- Assists in algorithm performance metrics development
- Enhances tools for APB(T) sea test reconstruction

Architecture

An important feature of the testbed is a flexible test architecture (Fig. 1) that enables the replay of acoustic and nonacoustic data sources to the systems being evaluated. The testbed system consists of a number of Pentium, Sun, and Hewlett Packard workstations running the following software: Tactical Record and Playback System, Multi-Sensor Display, Rapid Assessment Display, Target Motion Analysis algorithms, and ARCI Engineering Workstation.

Software Tool Development

A number of general-purpose tools were developed to automate data conversion, transport, playback, and archiving. Examples include data reduction tools for data conversion, filtering, and parsing; a Java middleware wrapper to serve as an isolation layer between multipurpose transportable middleware and other applications; a data playback and capture utility for playback and capture of middleware messages; and the ARCI Engineering Workstation, which supports data and screen capture.

APL Contributions

The APB(T)-01 testbed system has given software and algorithm developers a controlled laboratory environment for the testing and analysis of close encounter algorithms. APL staff members have also provided independent algorithm verification, hardware and software support, and data collection support. Moreover, the Laboratory has provided key recommendations for future improvements to the system. The testbed methodology is instrumental to both current and future submarine warfare projects.

CONCLUSION

The Laboratory's National Security Technology Department continues to make significant contributions to APB/ARCI and to the larger field of information management. Substantial improvements in the quality and timeliness of information have been, and continue to be, delivered to the Fleet. An eye toward the future (shown for APB/ARCI in Fig. 2) reveals plans not only to extend these improvements, but also to add capabilities not even imagined only a few years ago. NSDT, working with government and industry, will see these sizable information management system improvements transition from thought to reality.
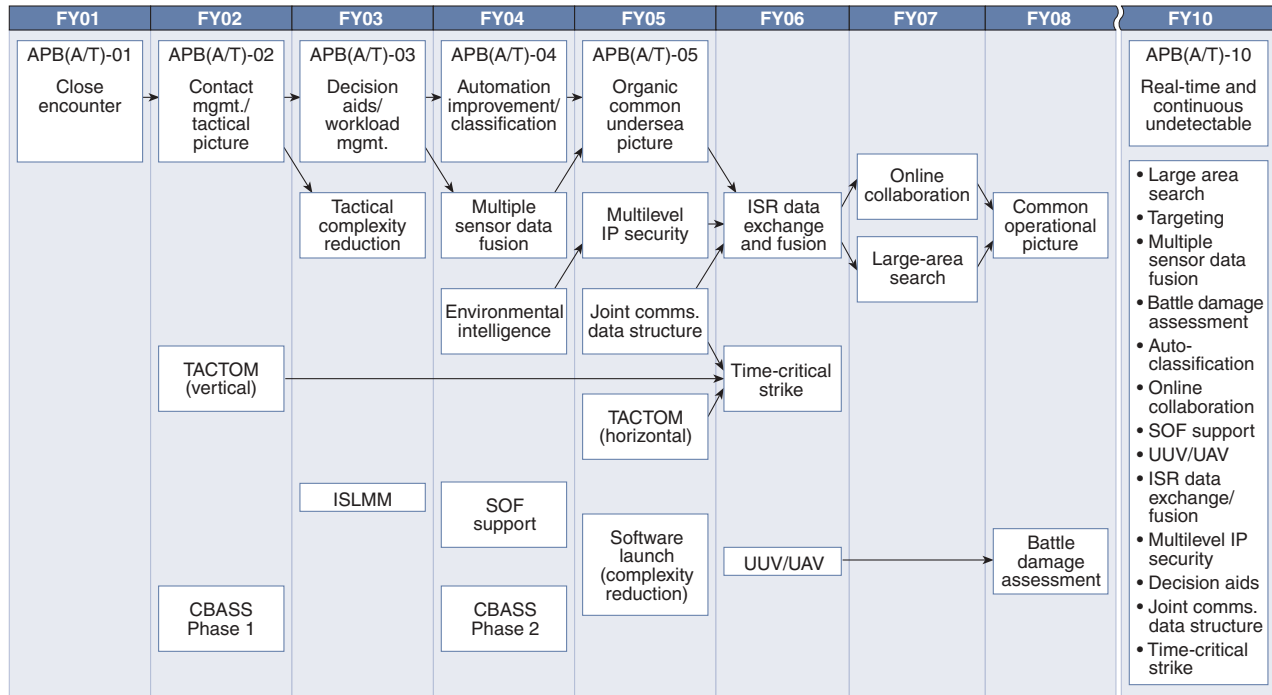
FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY10
APB(A/T)-01	APB(A/T)-02	APB(A/T)-03	APB(A/T)-04	APB(A/T)-05				APB(A/T)-10
Close encounter	Contact mgmt./ tactical picture	Decision aids/ workload mgmt.	Automation improvement/ classification	Organic common undersea picture				Real-time and continuous undetectable

Figure elements:
- Tactical complexity reduction (FY03)
- Multiple sensor data fusion (FY04)
- Multilevel IP security (FY05)
- ISR data exchange and fusion (FY06)
- Online collaboration (FY07)
- Large-area search (FY07)
- Common operational picture (FY08)
- Environmental intelligence (FY04)
- Joint comms. data structure (FY05)
- TACTOM (vertical) (FY02)
- Time-critical strike (FY06)
- TACTOM (horizontal) (FY05)
- ISLMM (FY03)
- SOF support (FY04)
- Software launch (complexity reduction) (FY05)
- UUV/UAV (FY06)
- Battle damage assessment (FY08)
- CBASS Phase 1 (FY02)
- CBASS Phase 2 (FY04)

APB(A/T)-10 (FY10):
- Large area search
- Targeting
- Multiple sensor data fusion
- Battle damage assessment
- Auto-classification
- Online collaboration
- SOF support
- UUV/UAV
- ISR data exchange/ fusion
- Multilevel IP security
- Decision aids
- Joint comms. data structure
- Time-critical strike

Figure 2. APB/ARCI evolutionary path. (CBASS = Common Broadband Advanced Sonar System, ISLMM = Improved Submarine-Launched Mobile Mine, ISR = Intelligence, Surveillance, and Reconnaissance, SOF = Special Operations Forces, TACTOM = Tactical Tomahawk, UUV/UAV = Uninhabited Underwater Vehicle/Uninhabited Aerial Vehicle.)

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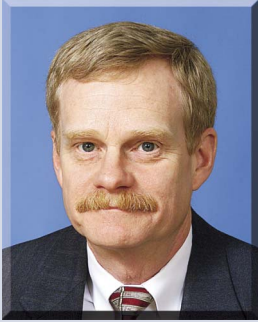
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