12 Call –

B-5 Nuc det – 10^{-9}.

B-6 MUSA Lite of 35 gnd x.

B-7 SPS – 10^{-6} (4b TNi).

B-10 MUCA – 35 gn tiles.

Ex Sum "Effectiveness studies show significant value to new MUCA M.O.B. options for capabilities against harder targets".

9-10 Weapon system reliability assumed 0.89

ExSum Several candidates more effective than MUSICS 88 at original accuracy objective" (cq)

Leading candidates do not have 2 sats in final design.

MUCA [...] candidates offer part reuse

5-23 MC 3810

5-28 CAS-2 W76t

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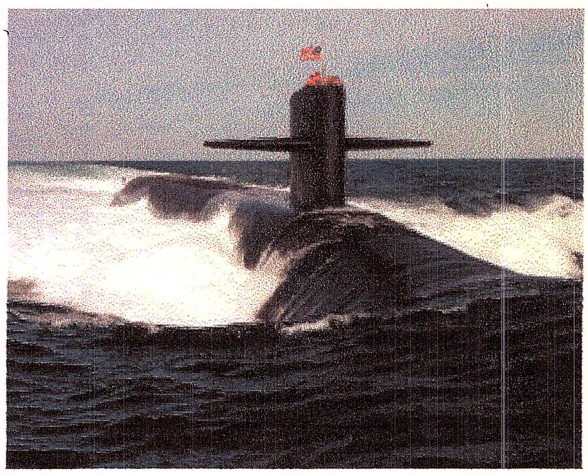
Strategic Systems

Introduction - Operational Assessment - Accuracy - Underwater Launch Range Systems - MMIII Guidance - **Training** - SSGN - Nuclear Surety

Introduction



APL has been involved with the nation's Submarine Launched Ballistic Missile program since its inception in the early 1960s. APL's efforts provide the U.S. Navy with assurance that the Trident Strategic Weapon System is reliable, accurate, and will respond as predicted. This assurance is determined by a comprehensive test and evaluation program that quantifies system performance. The test and evaluation program is designed to measure system performance from initial deployment through the end of the weapon system life cycle. The performance estimates are provided to the Operational Commanders, who incorporate measured system performance into strategic planning. The analysis of ship and fleet performance is also reported to the Navy so that emergent problems can be addressed in a timely fashion.

APL's technical expertise is also being applied to the following technology developments and strategic programs:

- United Kingdom's Trident Weapon System evaluation program
- Development of a new generation GPS translator tracking system for USAF Minuteman III guidance accuracy evaluation and range safety
- SSGN Tomahawk underwater launch risk assessment, Attack Weapon System integration, requirements development, and test & evaluation planning

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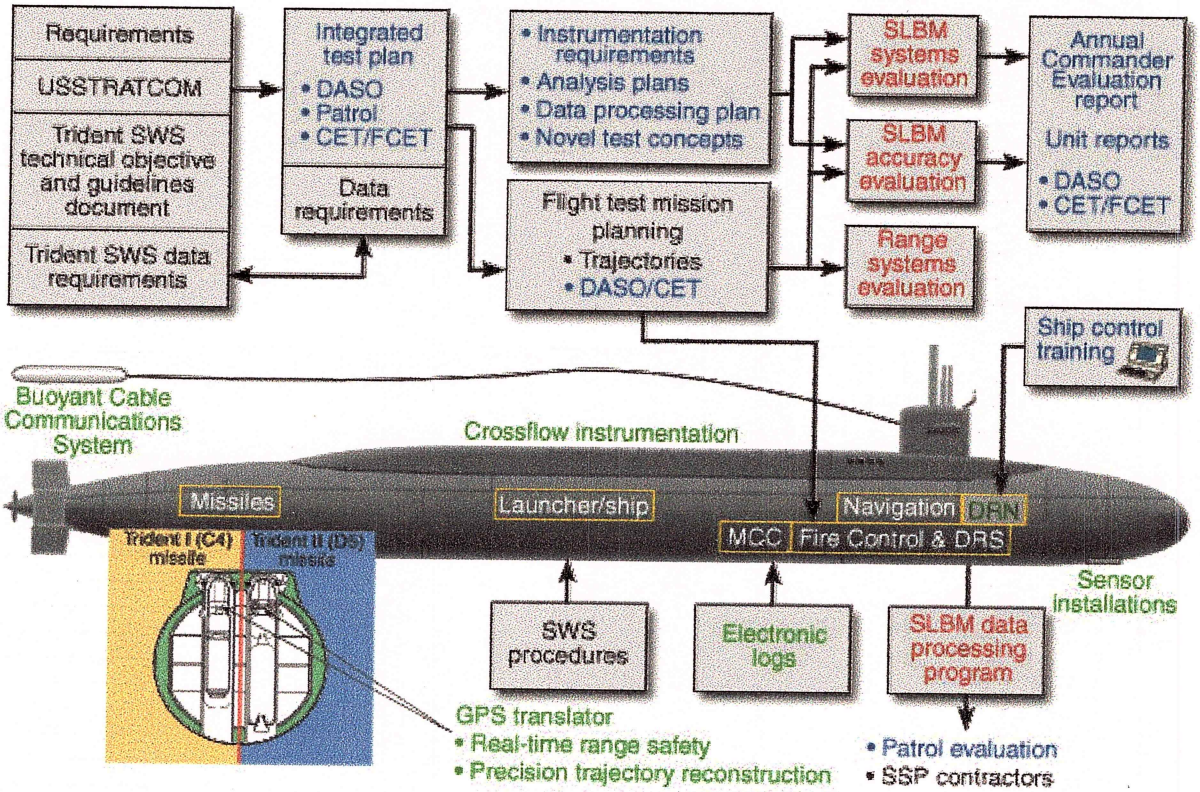
Strategic Systems

Introduction - Operational Assessment - Accuracy - Underwater Launch Range Systems - MMIII Guidance - Training - SSGN - Nuclear Surety

Operational Assessment

APL's Strategic Systems Program Area provides assurance that the Trident I and II weapon systems are reliable and accurate, using a rigorous test and evaluation program, which includes evaluation of performance during routine operations at sea, all the way to evaluation of periodic test launches (for which the Program Area also provides support). Trident missile accuracy is measured using extensive instrumentation and specialized processing facilities in the Strategic Systems Department (SSD). Those results are used to develop and refine high-confidence predictive submarine-launched ballistic missile accuracy models. APL continues to plan and evaluate Trident Strategic Weapons Systems tests in order to develop the detailed system understanding to not only predict operational system performance but also provide the first indicators of the effects of aging to determine which system elements need to be replaced.



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 = missile control center, DRS = Data Recording System, DRN = DASO Reference Navigator.)

The three primary Trident Weapon System test programs are (1) Demonstration and Shakedown Operations (DASOs), (2) Patrol Evaluation, and (3) Commander Evaluation Tests (CETs) or Follow-on CETs (FCETs).

DASO

Strategic Systems Department personnel provide support for system certification, via the Demonstration and Shakedown Operation (DASO) program. DASO consists of a series of exercises conducted by both crews of the SSBN over several weeks, both in-port and at-sea, intended to verify the readiness of the SWS and crew to begin patrol. DASOs are generally

conducted after an SSBN is first built and after an SSBN receives a major upgrade and often culminate in a test missile launch. Strategic Systems participates throughout DASO by providing independent evaluation of the readiness of the SWS to begin patrol, supporting the naval personnel that issue the system's certification, developing special tests, and providing crew training.

Patrol Evaluation

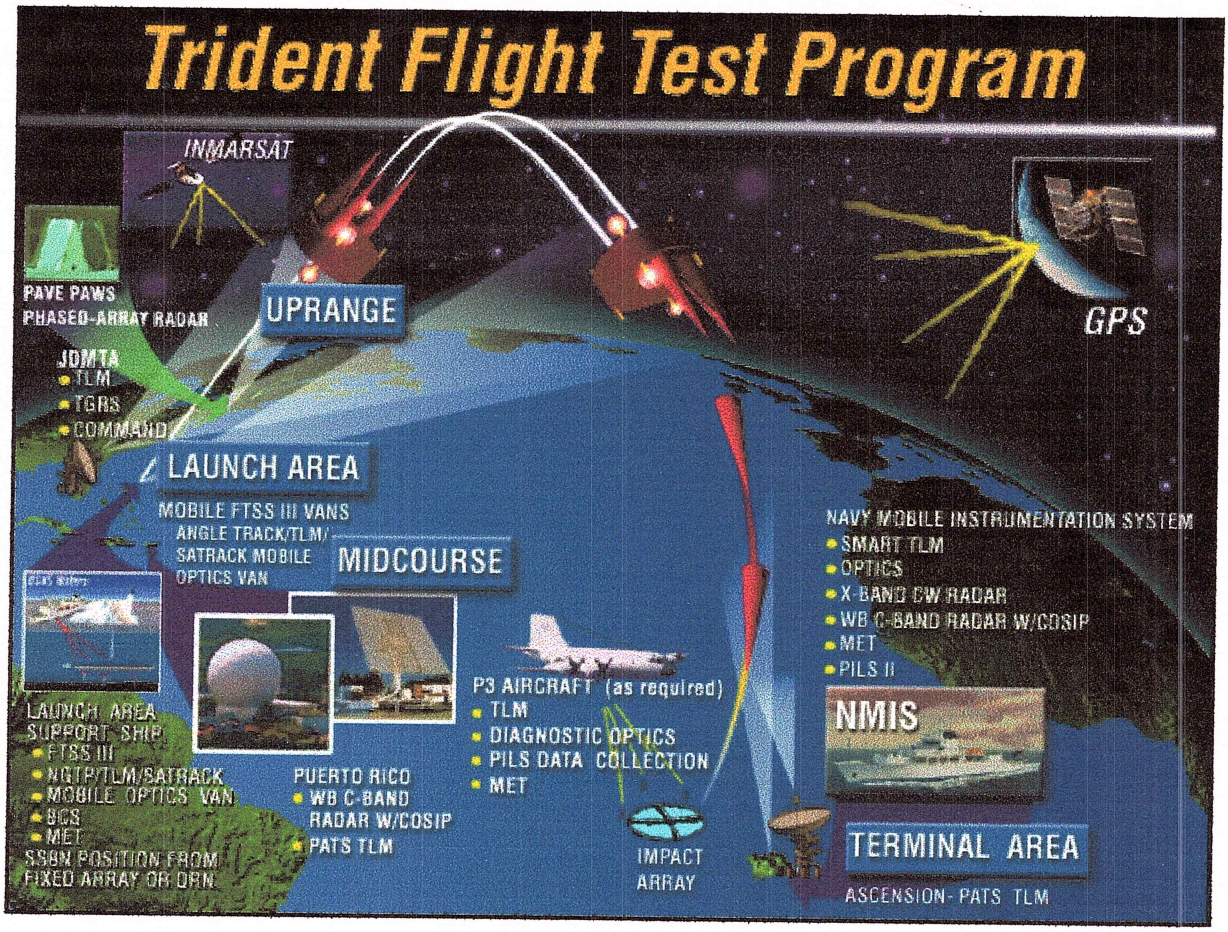
Each SSBN and weapon system may be deployed for a decade or more. The continuous monitoring of each SSBN identifies hull-unique problems as well as fleet trends that may evolve or change with time and affords a current, cumulative weapon system performance estimate, which is critical to maintaining the credibility of this strategic deterrent system. The objectives of patrol evaluations are to (1) provide weapon system performance information in the actual patrol environment for use in deriving performance planning factors, (2) provide Navy Fleet Operational Commanders and Strategic Systems Programs (SSP) with an independent system evaluation of each SSBN and its weapon system strategic deterrent patrol, and (3) provide individual SSBN crews with an analysis of the performance of their weapon system during patrol.

CET/FCET

The Commander Evaluation Tests (CETs) or Follow-on CETs (FCETs) are continuing operational tests that involve random selection of Trident II ships and missiles for test launches. The results of these tests provide annual performance estimates of the Trident II Weapon System. The objectives of this test 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. Missiles are selected randomly from the onboard complement of tactical missiles and are converted to a test configuration after returning to port. Following the conversion, the submarine proceeds to a launch area and resumes operations as if on a strategic deterrent patrol. A launch message is transmitted via strategic communications links and the submarine conducts a launch of the selected missiles.

Data is obtained from instrumentation onboard the SSBN, from a launch area support ship, and from downrange support sites (on ship, aircraft, and land) that provide the information necessary for strategic systems analysts to assess total weapon system performance.


Trident Flight Test Program
INMARSAT
PAVE PAWS
PHASED-ARRAY RADAR
UPRANGE
GPS
JDMTA
• TLM
• TGRS
• COMMAND
LAUNCH AREA
MOBILE FTSS III VANS
ANGLE TRACK/TLM/
SATRACK MOBILE
OPTICS VAN
MIDCOURSE
NAVY MOBILE INSTRUMENTATION SYSTEM
• SMART TLM
• OPTICS
• X-BAND CW RADAR
• WB C-BAND RADAR W/COSIP
• MET
• PILS II
NMIS
P3 AIRCRAFT (as required)
• TLM
• DIAGNOSTIC OPTICS
• PILS DATA COLLECTION
• MET
LAUNCH AREA
SUPPORT SHIP
• FTSS III
• NGTP/TLM/SATRACK
• MOBILE OPTICS VAN
• BCS
• MET
SSBN POSITION FROM
FIXED ARRAY OR ORN
PUERTO RICO
• WB C-BAND
RADAR W/COSIP
• PATS TLM
IMPACT
ARRAY
TERMINAL AREA
ASCENSION - PATS TLM

Strategic Systems

Trident Accuracy Program

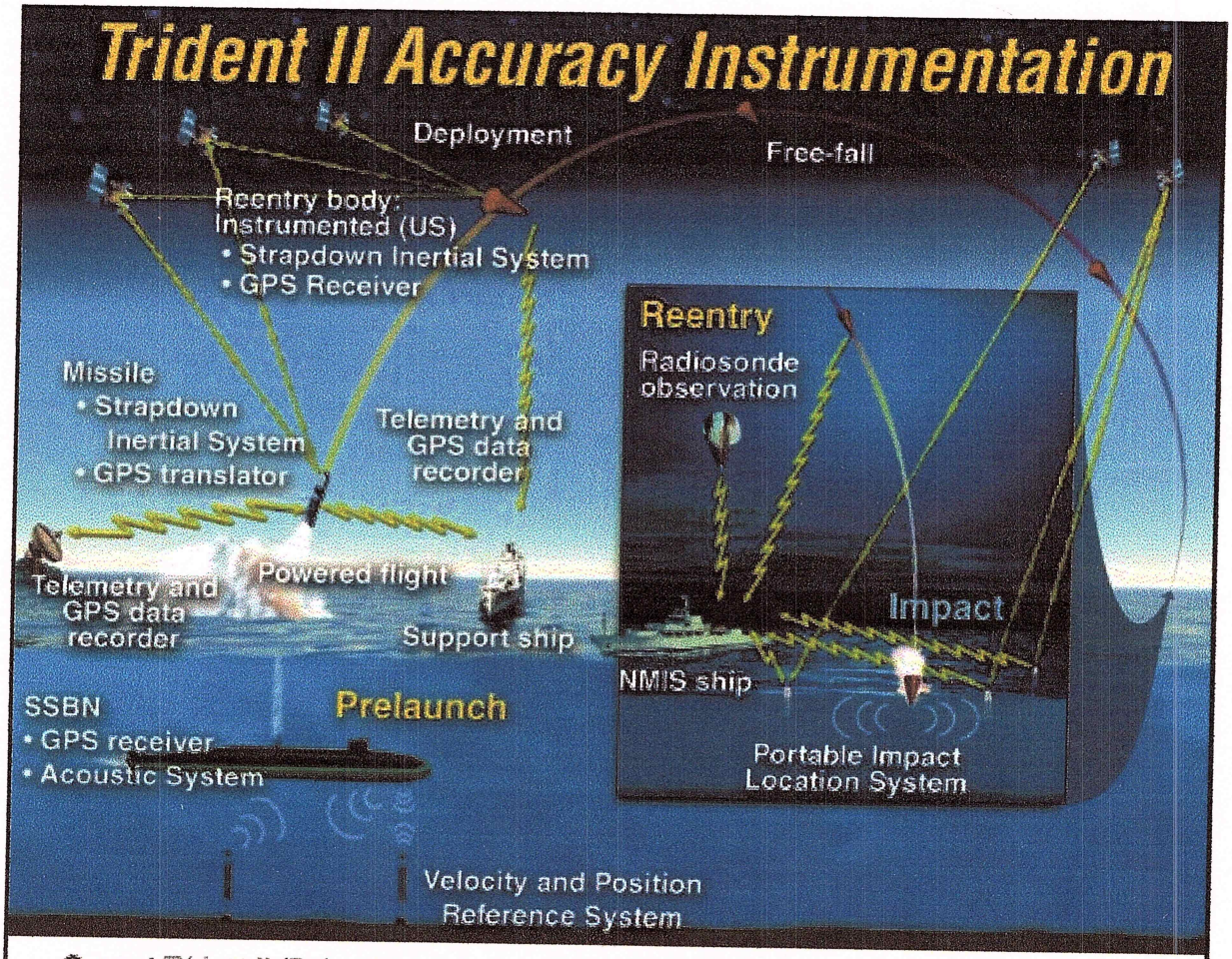
Background

The accuracy of submarine-launched ballistic missiles has been assessed for all generations of the Fleet Ballistic Missile, but the requirement for high accuracy for the Trident II (D5) weapon system brought with it a requirement to have greater confidence in that assessment. The Trident Accuracy Program was introduced to develop the instrumentation, methodology, and expertise to enable APL to provide the Navy with accuracy estimates whose uncertainty could be quantified -- even for scenarios that are not fully explored in any test program.

Flight testing has always been an integral part of any assessment of the performance (accuracy, reliability, and readiness) of the Fleet Ballistic Missile accuracy but until the Trident Accuracy Program, the accuracy analysis consisted primarily of measuring the misses from the target and computing sample statistics. Flight test programs were designed to reflect expected tactical usage as much as possible, but there were test limitations that were necessitated by considerations of cost and flight test safety: in particular, limited areas from which flight tests could be launched and limited ranges for trajectories.

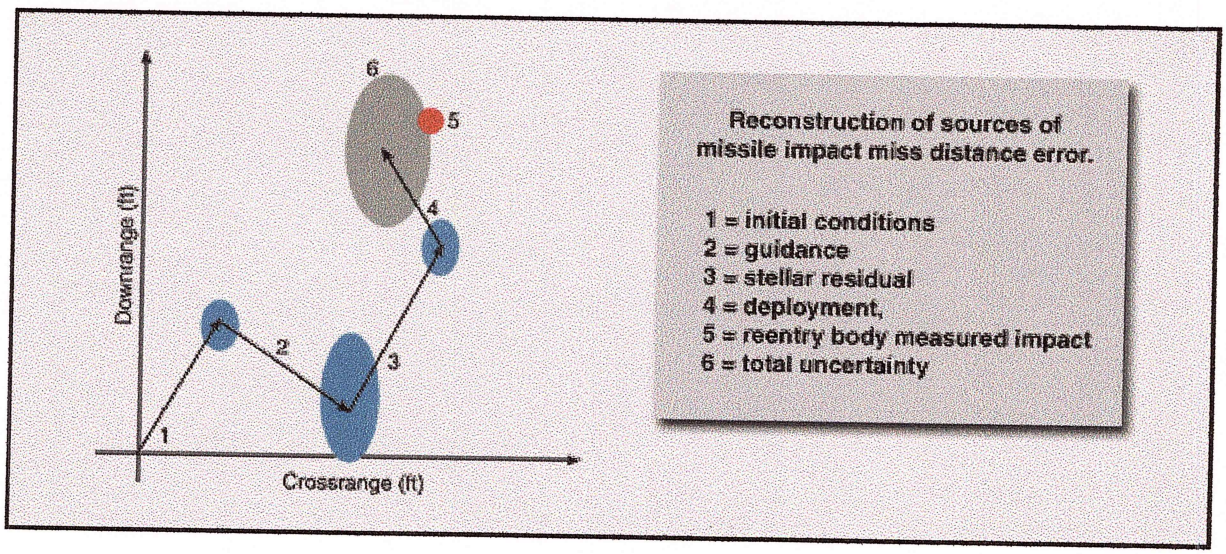
The New Approach - Test Instrumentation, Error Estimation, Model Prediction

The first aspect of the new approach introduced by the Trident Accuracy Program was to introduce new flight test instrumentation to allow accuracy assessment at a more fundamental level - even down to the level of specific accelerometer and gyroscope errors for the missile. The use of satellites for estimating the position of an object (viz., submarines on patrol) was first developed at APL and this capability was extended to allow the estimation of the position and velocity of a missile in flight. The Satellite Tracking (SATRACK) instrumentation and processing forms the heart of the new instrumentation employed in this new approach; the full set of flight test accuracy instrumentation is shown in the chart below.



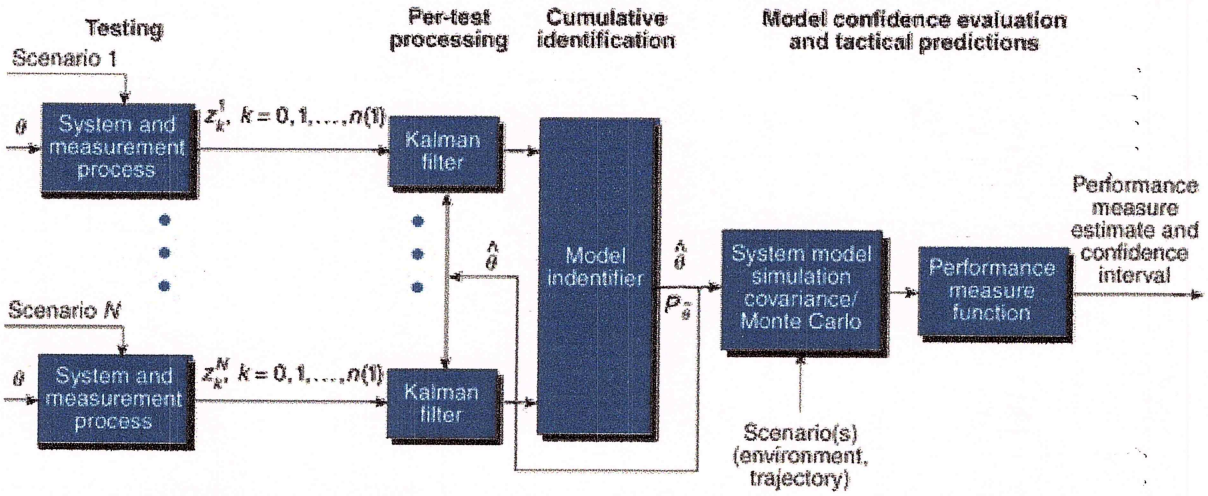
Current Trident II (D5) accuracy instrumentation suite. Measurements are made at every phase of a full-system test. (GPS = Global Positioning System)

This test instrumentation makes possible the second aspect of the Trident Accuracy Program: the estimation of individual errors that contribute to a total system miss. Data from each accuracy test is analyzed using some variant of a Kalman filter. Within the filters are the detailed models of both the system and instrumentation for each subsystem. This data is 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 behavior. Analysis results provide insight into the sources and causes of inaccuracy.



The instrumentation-based data is also used in the third new approach introduced by this program: the generation and use of an error model to provide estimates of system accuracy - with quantified confidence. 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 data. Although error models for ballistic missiles had been used before this program, they were never directly derived from weapon system test results. Previous models were validated or (or more often, invalidated) by comparison to the inherently limited flight test results, but the new approach allowed the model to be estimated - and allowed the generation of formal confidence bounds in those estimates.

The process figure here depicts notationally how this analysis is accomplished.



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

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.

Contributions

The Trident II Accuracy Evaluation Program has contributed to the success of the Trident Weapon System in several important ways:

· Instrumentation Requirements and Test Planning - models and simulations of accuracy evaluation supported rigorous quantitative trade-off studies.

· Accuracy Understanding - has provided unprecedented understanding of and confidence in system performance.

· System Improvements - improved models provide better system performance by way of embedded system **software** through the calculation of system gains used when processing guidance stellar sightings or reentry body fuze information, which relies on an accurate characterization of system performance. The calibration of

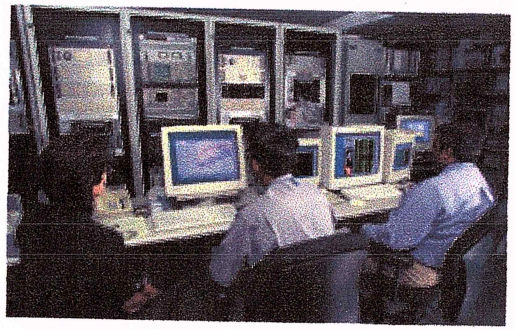
reentry body release parameters has been improved by knowledge gained from onboard inertial instrumentation.

· Accommodation of Testing Cutbacks - instrumentation and a rigorous analytical approach required less testing to achieve the desired initial confidence and also reduced follow-on testing of the deployed system.

Strategic Systems

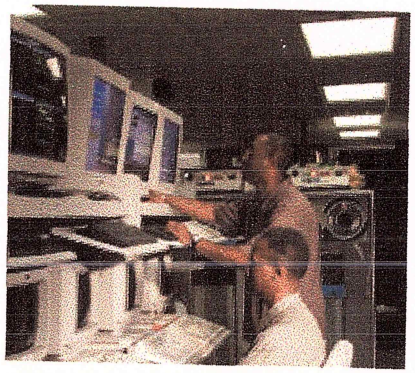
Air Defense | Biomedicine | Counterproliferation | Information Operations
Science and Technology | Space Science and Engineering | Strategic Systems | Precision Engagement
Undersea Warfare | Warfare Analysis | Technical Services | Conference Facilities

SATRACK and GPS Postflight Acquisition and Tracking Facility



The SATRACK Postflight Acquisition and Tracking Facility processes recorded, translated Global Positioning System (GPS) satellite signals collected in support of Trident missile test flights. The **hardware/software** systems within the facility convert these signals into range and Doppler measurements that are used for Trident weapon system evaluation. The facility is also used to process signals in support of National Missile Defense Integrated Flight Tests, to performance-test translator flight **hardware**, to evaluate commercial GPS receivers and process signals in support of USAF Minuteman III Guidance Replacement Program Flight Tests. One system within the facility continuously tracks GPS signals from a roof-mounted antenna to provide GPS integrity monitoring.

SLBM Distributed Data Processing System (DDPS)



The Submarine-Launched Ballistic Missile (SLBM) DDPS is a computing facility specifically designed to assess the Navy's SLBM Weapon System. To perform this task, tests are conducted that stress the SLBM Weapon System and crew. During these tests, instrumentation data are collected and later analyzed by APL to independently evaluate SLBM performance and accuracy. The results of the tests are provided to the SLBM crew and the Navy sponsor; summary results are provided annually to the Joint Chiefs of Staff. As part of the ongoing evaluation, special studies and tests are devised and conducted. The SLBM DDPS is used in direct support of this mission.