

THE POSTMISSION PROCESSOR FOR THE SONOBUOY MISSILE IMPACT LOCATING SYSTEM

A postmission processing software package analyzes recorded acoustic data and produces highly accurate solutions for the time and location of missiles impacting the ocean surface. The impacts occur within a pattern of pinging sonobuoys drifting above an array of deep-ocean transponders anchored to the seafloor. Transmitted acoustic signals are recorded aboard the deploying aircraft for later input into the postmission processor, which computes characteristics of ocean sound propagation and solves for sonobuoy positions and impact times and locations.

INTRODUCTION

The Advanced Range Instrumentation Aircraft/Sonobuoy Missile Impact Locating System (ARIA/SMILS) is an airborne ground-based system developed to score ballistic missile tests in worldwide deep-ocean transponder (DOT) arrays. It was designed and developed by APL's Space Department¹ for the 4950th Test Wing at Wright-Patterson Air Force Base (Fig. 1). The ARIA/SMILS produces solutions for the time and geodetic location of missile impacts occurring near a pattern of drifting sonobuoys positioned on the ocean surface above a DOT array. Although the SMILS concept has been in use for over twenty years, the ARIA/SMILS was designed to provide an improved, modernized, and automated system. Previously, a separate aircraft was required to perform the SMILS function, whereas the ARIA/SMILS adds the scoring capability to the ARIA already in use during missile tests for gathering telemetry data. In addition, the ARIA/SMILS uses sophisticated computer software to reduce the need for operators with specialized analytical experience and to minimize the time required to produce scoring reports.

The ARIA/SMILS concept involves deploying a pattern of sonobuoys on the ocean surface, above an already existing DOT array. The aircraft first deploys an aircraft-launched expendable bathythermograph (AXBT) buoy or an aircraft-launched sound velocimeter (AXSV) buoy, which descends through the ocean and measures sound speed as a function of depth. Subsequently, three types of sonobuoys are deployed in a standard pattern over the DOT array: air-deployable interrogator (ADI) buoys, which transmit both surface pings and interrogation pings that trigger response pings from the DOT's on the ocean floor below; low-frequency pinger (LFP) buoys, which transmit surface pings only; and high-frequency (HF) buoys, which are passive and do not transmit any pings. All of the sonobuoys can hear any surface or DOT pings, as well as acoustic events associated with reentry

vehicle (RV) impacts. Acoustic signals heard by the sonobuoy hydrophones are relayed to the ARIA via RF uplinks.

The ARIA/SMILS processing software solves for the ADI buoy positions, relative to the DOT's on the ocean floor, by using the round-trip times between transmission of interrogation pings and reception of associated DOT responses. The LFP and HF buoys are, in turn, navigated relative to the ADI buoys by using propagation times of surface pings. Ultimately, RV impact positions are solved for by using all of these relative locations, together with the geodetic positions of the DOT's (from survey data) and a table of times for impact splashes as detected at each of the sonobuoys. The ARIA/SMILS contains a flight system encompassing the aircraft-based hardware and software necessary for real-time support of missile tests. This system allows for data collection and preliminary impact scoring. In addition, the ARIA/SMILS consists of a ground-based postmission analysis system (PMAS), which analyzes recorded data to produce final scoring reports.

The flight system comprises the hardware and software needed to guide the ARIA to the DOT array used for a given missile test. It aids the aircraft in deploying a pattern of air-launched sonobuoys over the DOT array and records and processes the signals transmitted by the sonobuoys throughout the test. These signals consist of acoustic data transmitted to the aircraft from the sonobuoys via RF uplinks. The acoustic signals are also recorded on an analog tape aboard the aircraft. Real-time processing by flight system software uses the acoustic data to determine buoy positions and locations of RV impacts. The solutions produced in real time aboard the aircraft provide a quick-look RV impact scoring report, whereas the ground-based PMAS segment processes the recorded analog tape to produce a more accurate scoring report. (A more detailed discussion of the ARIA/SMILS may be found in the article by McIntyre in this issue.)

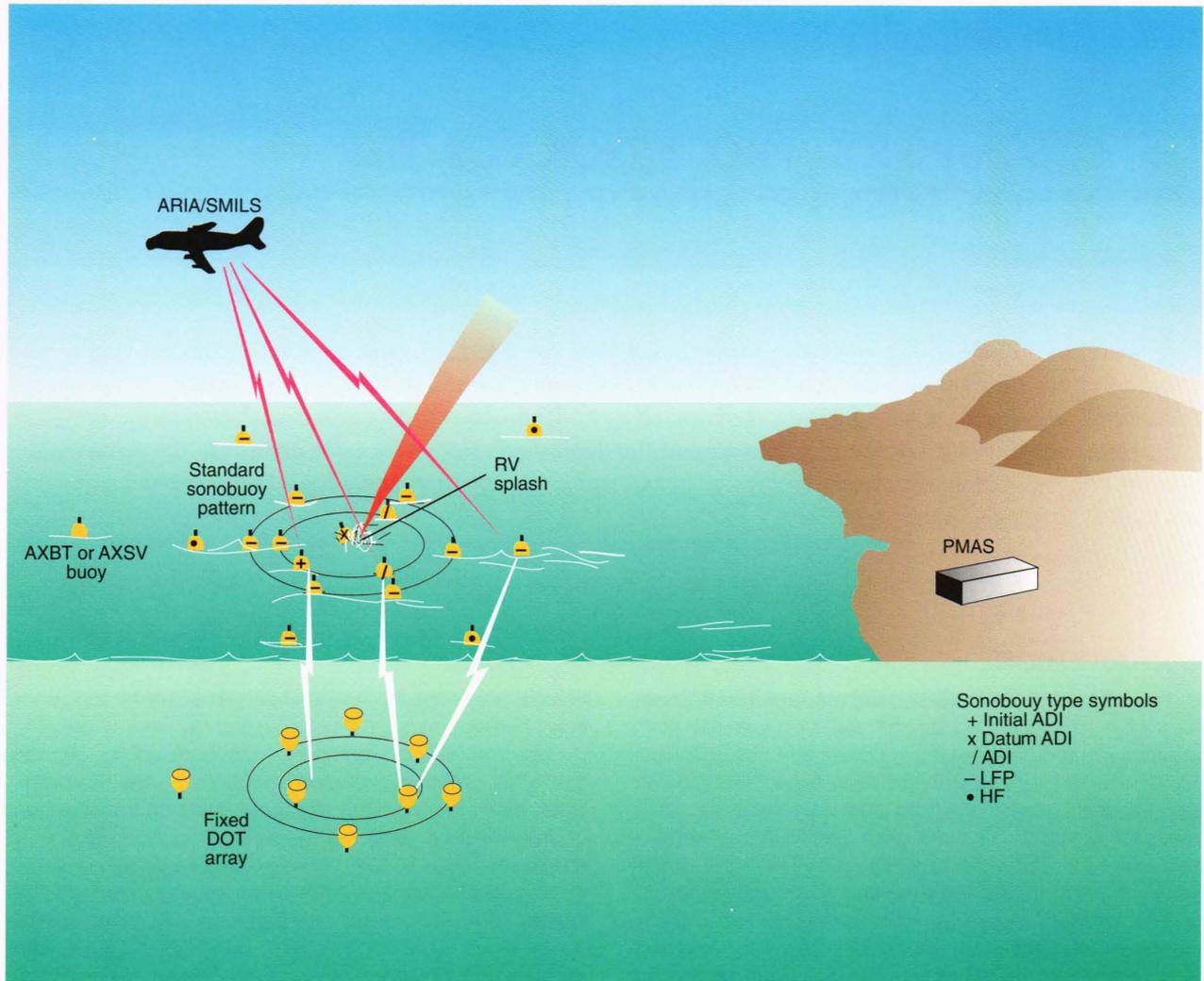


Figure 1. Diagram showing the primary components of the Advanced Range Instrumentation Aircraft/Sonobuoy Missile Impact Locating System (ARIA/SMILS). A specially equipped aircraft deploys a pattern of sonobuoys above an array of deep-ocean transponders (DOT's). Recorded acoustic data are processed by the postmission analysis system (PMAS) to produce highly accurate solutions for the times and locations of reentry vehicles (RV's) impacting the ocean surface near the buoy pattern. Buoy types are: aircraft-launched expendable bathythermograph (AXBT); aircraft-launched sound velocimeter (AXSV); air-deployable interrogator (ADI); low-frequency pinger (LFP); and high frequency (HF).

OVERVIEW OF THE POSTMISSION ANALYSIS SYSTEM

The PMAS has two parts: the postmission preprocessor and the postmission processor (PMP). Both systems can operate independently of each other, although they are installed in the same computer facility.

The preprocessor encompasses the hardware and software needed to process the analog acoustic data recorded on tape by the flight system. It recovers all significant acoustic events from these signals. The preprocessor is a MicroVAX-3 computer specially equipped with analog-to-digital converters, a time code generator, and an array processor. It remotely controls playback of tape channels on an analog tape transport, digitizes the analog acoustic signals, and analyzes the digital data stream to detect the time of the leading edge of all acoustic events occurring at frequencies of interest.

The preprocessor is designed to detect the following: the marker tone indicating the transmission of a ping by an ADI or LFP sonobuoy; surface pings that can be received by ADI, LFP, or HF buoys; DOT response pings at ten unique frequencies as heard by any buoy; and RV impact splashes as heard by any buoy. In addition, it analyzes recorded acoustic signals from AXBT and AXSV buoys to obtain data from which a profile of sound speed versus ocean depth may be computed. The acoustic event times and sound velocity data are passed to the PMP segment of the PMAS as computer-compatible files in character format.

The PMP is a menu-driven software package resident on the MicroVAX-3 computer.^{2,3} Using the input data from the preprocessor, the PMP processes the time-tagged acoustic events to produce highly accurate solutions for the RV impact times and geodetic positions. It also manages database files of DOT coordinates and profiles

of historical ocean sound data, and produces a tape of initialization data for the flight system before the start of a SMILS mission.

The authors' area of responsibility in PMAS development was the design of the PMP software. The remainder of this article will therefore address in more detail the processing capabilities of the PMP.

THE POSTMISSION PROCESSOR

A functional block diagram of the PMP is shown in Figure 2. The software package is implemented as one Fortran main program and about 140 submodules. All PMP processing steps are controlled by the PMP menu-oriented user interface, which manages all operator interactions and file handling.

Although the primary service provided by the PMP is that of postmission processing, it can also perform several ancillary operations (see External functions in Fig. 2). A database is maintained to store files of DOT array geodetic coordinates and historical profiles of ocean sound velocity for each DOT array location. Furthermore, the PMP can produce a digital tape of initialization data for the ARIA/SMILS flight system.

The most significant role of the PMP, however, is to produce RV impact solutions. After a SMILS mission has

been flown, the analog tapes recorded aboard the ARIA are returned to the PMAS facility at Wright-Patterson Air Force Base. Typically, the preprocessor needs about eight hours to process the analog data and produce tables of sonobuoy ping times and splash detection times, along with sound speed measurement data. These character-format files are transferred to the PMP computer, whereupon an operator invokes the PMP software and controls the remainder of the processing via selection of options presented in a series of on-screen menus. The control software of the PMP manages the presentation of these menus, operator entries, and the display of appropriate warning messages should any subordinate processes encounter an error.

The first step in the PMP processing sequence is to duplicate the preprocessor input files to field "working" copies and satisfy system requirements to be able to revert to original, unmodified input data. Specifically, input data from the preprocessor consist of four files:

1. A ping table, which gives the receive time of every ping heard at every buoy. The SMILS buoys can hear a surface ping transmitted by any other ADI or LFP buoy or a DOT ping transmitted in response to an interrogation ping from an ADI buoy. The preprocessor generates a time-ordered list of all received pings, along with an

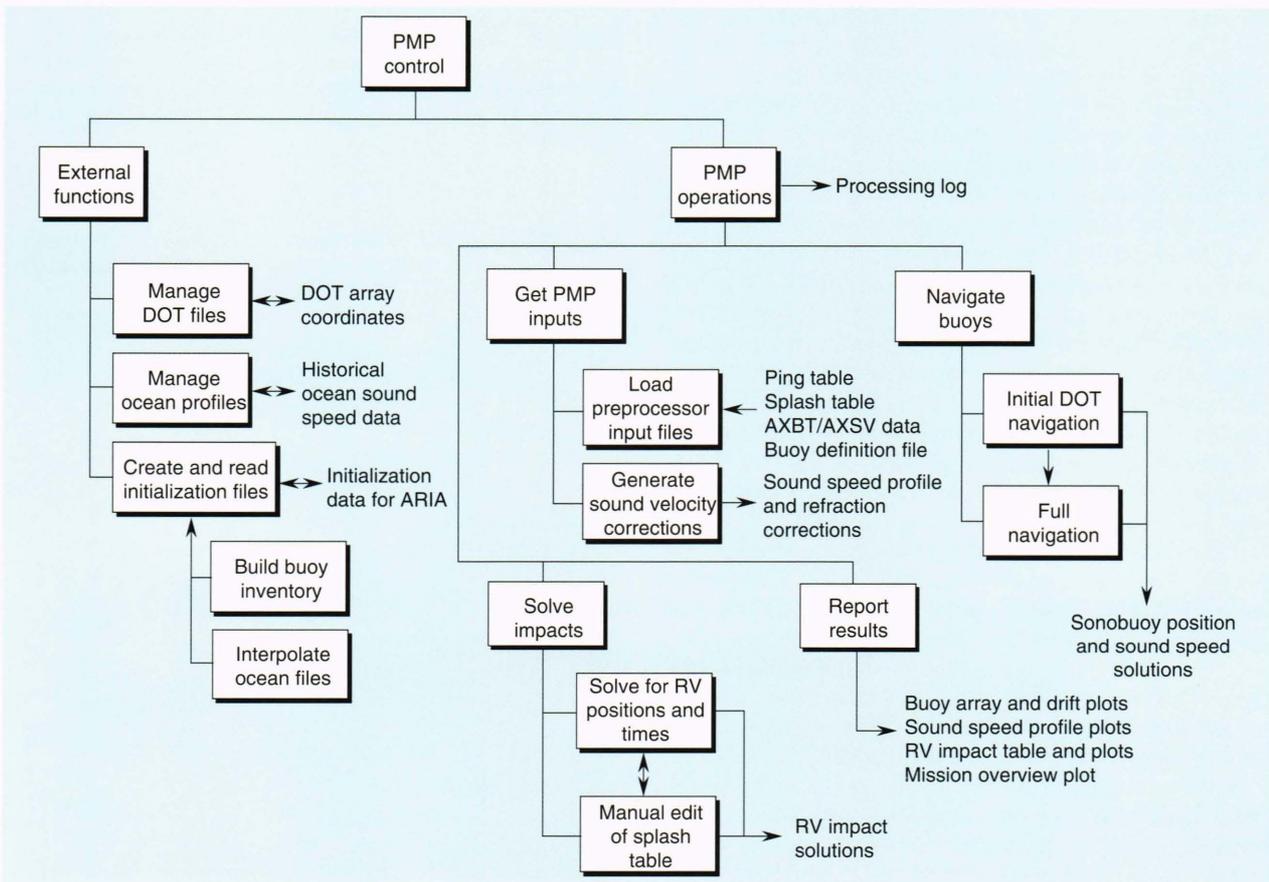


Figure 2. Functional block diagram of data processing capabilities provided by the postmission processor (PMP). The hierarchy of functions closely resembles the on-screen menu options presented to the operator. (See Fig. 1 caption for an explanation of the terms used here.)

identification of the receiving buoy, the ping frequency (surface ping or one of ten DOT frequencies), and the transmitting buoy. The latter is deduced by the preprocessor's sorting software, which matches periods of received ping times to the known, unique transmitting period of each buoy.

2. A splash table, which gives the receipt time of every impact splash detected at each buoy.

3. An AXBT/AXSV profile, which is simply a table of output frequency versus descent time from one of these environmental buoys.

4. A buoy definition table, which identifies buoy types (ADI, LFP, or HF) and analog tape channels associated with each SMILS buoy (maximum of sixteen).

By using these four input files, along with a file of DOT coordinates for the array at which the mission took place and a historical ocean sound profile for that array, the PMP sequentially invokes three major processes: sound velocity processing, sonobuoy navigation, and impact solutions.

Sound Velocity Processing

To solve for sonobuoy positions and RV impacts, the PMP has available only time tags representing the transmission or reception of an acoustic event; these can be converted to range measurements by multiplying propagation times by the speed of sound in water. But the speed of sound in the ocean is a function of pressure, temperature, and salinity.⁴ The environmental AXSV and AXBT buoys are designed to measure the variation of sound speed with ocean depth (the former directly measures sound speed and the latter measures temperature, from which sound speed may be computed). The ARIA deploys one of these buoys during the SMILS mission, and the frequency of its returned acoustic tone can be related to sound speed via an algorithm specified by the buoy manufacturer. The PMP processes the table of descent time and frequency measurements provided by the preprocessor and produces a profile of sound speed versus depth. Since each environmental buoy returns measurement data only to some maximum depth, a historical ocean profile provided by the Fleet Numerical Oceanographic Center is used to complete the profile down to the ocean floor. Merging of measured and historical data is accomplished by a decaying exponential technique to limit the discontinuity at the transition point.

An example of a sound velocity profile produced by the PMP, based on data from an AXSV buoy, is shown in Figure 3. A slight "hook" appears within the top 50 m of the profile, indicating the presence of a surface duct, which facilitates the propagation of sound in the surface layer of the ocean. Such a duct is desirable for optimal ARIA/SMILS results, since it allows for maximum range for sonobuoys to hear pings transmitted along the surface.

Another complication of variable sound speed in the ocean is the effect of refraction (bending of ray paths) between buoys on the surface and DOT's on the ocean floor.^{4,5} Buoy navigation software must compensate for this phenomenon, which affects the time difference between transmission and reception of a ping from the buoy-DOT or DOT-buoy. A ray tracing technique is used

to evaluate the effect of refraction. By using the sound speed profile, the ocean is represented as a series of horizontal layers, and the bending of a ray emanating from the ocean floor may be computed at the junction of each layer. The result is a range difference between the straight slant-range path and the refracted path, which yields the range correction appropriate for that particular ray. The refraction effect is shown in Figure 4.

The PMP software actually computes the range correction needed for each of a family of ray paths, ranging from vertical to the maximum angle encountered in go-

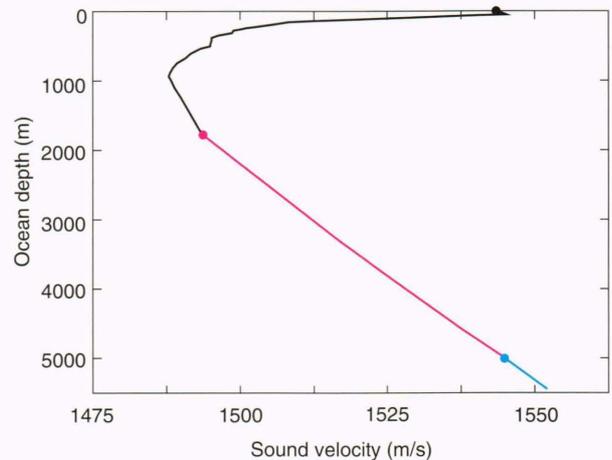


Figure 3. Example of ocean sound speed profile produced by the PMP using measured data from an aircraft-launched expendable sound velocimeter buoy (black). A historical profile is merged (red) and extrapolated (blue) to complete the profile down to the ocean floor.

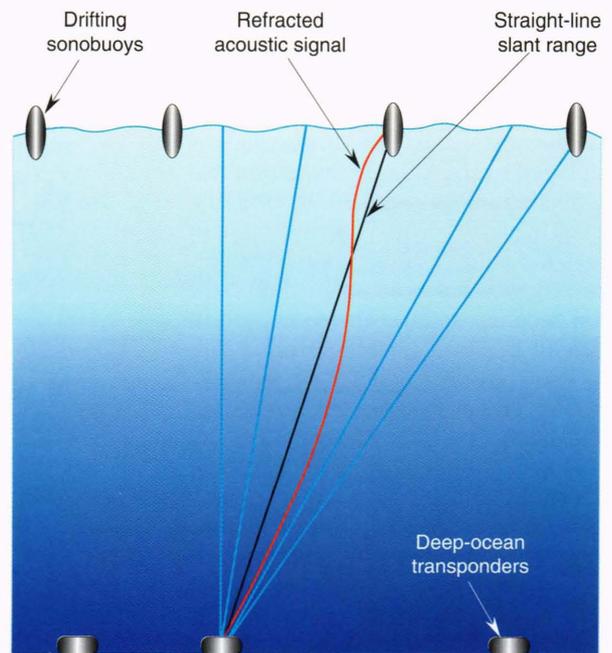


Figure 4. Straight-line slant range and the associated refracted ray path (exaggerated). A ray tracing algorithm is used to compute the refraction correction for a family of slant ranges.

ing from a DOT to a sonobuoy at the extreme edge of the buoy pattern drifting above. Thus, a series is produced, representing the refraction correction versus slant range. A third-degree polynomial is fitted to this set of corrections; therefore, subsequent buoy navigation software need only evaluate the polynomial for any specific slant range to correct for refraction. Also computed from the profile are an average horizontal sound speed in the surface layer and an average vertical sound speed (the harmonic average of all sound speed measurements in the profile, obtained from tracing the path of a vertical, undeflected ray).

Sonobuoy Navigation

Buoy navigation software uses the ping table to solve for the positions of buoys in the SMILS pattern relative to the fixed DOT array, which provides a surveyed geodetic reference. The preprocessor yields a table listing detection times for all pings transmitted over a 15- to 30-min span, centered about the time during which RV impacts occur. The SMILS buoy pattern nominally includes sixteen buoys, each transmitting pings at a rate of about one per minute. Three of these are ADI buoys, which simultaneously transmit DOT interrogation pings that elicit return pings from ten to twenty DOT's. These pings, in turn, may be heard by any of the sonobuoys. Thus, the ping table can easily contain several thousand ping detections, some of which may be false alarms caused by detection errors. Again, the preprocessor identifies the receiving buoy for each ping and the transmitting DOT or buoy (whether simply a surface ping or an interrogation ping eliciting a DOT response).

Implemented in the buoy navigation software is an iterative, batch, linearized least-squares technique, which simultaneously solves for the (x, y) position and velocity of each buoy relative to the DOT array center. Solutions are nominally produced at 1-min increments over the time span encompassed by the ping table. As with any least-squares process, a solution is computed as a correction to an initial estimate. The software uses as starting position estimates the known pattern designed to be deployed by the ARIA. Although some scrambling occurs in relating buoys recorded on arbitrary tape channels to actual pattern positions, a start-up navigation mode refines the initial estimates by using only DOT pings until convergence has been attained (i.e., the position correction becomes small). Thereafter, a full-navigation mode uses all DOT and surface pings to solve simultaneously for buoy positions and velocities, as well as the horizontal and vertical sound speed values that best fit the available data.

For each 1-min time increment at which a solution update is to be generated, all pings transmitted within a 5-min window centered about that time point are selected from the ping table. By using the current estimated solution state vector and the known DOT position coordinates, residuals are computed that represent the difference between measured and predicted ping propagation times. For example, consider a propagation path from buoy j to buoy k . Let σ^* be the measured transmit time of a ping at buoy j , and let t^* be the corresponding mea-

sured receive time of a ping at buoy k . The measured propagation time δ^* is then given by $\delta^* = t^* - \sigma^*$. The predicted propagation time $\hat{\delta}$ is computed as

$$\hat{\delta} = \frac{1}{V_p} |\hat{B}_k(t^*) - \hat{B}_j(\sigma^*)|,$$

where $\hat{B}_k(t^*)$ and $\hat{B}_j(\sigma^*)$ represent the positions of the receiving and transmitting buoys, respectively, and V_p is the speed of sound. The absolute value of the difference in buoy positions represents the propagation path length from buoy j to buoy k , depending on the ping type. For a surface ping, the propagation path length is the difference in the two buoy positions; for a received DOT ping, it is the net buoy j -DOT-buoy k path. The value used for V_p is chosen accordingly: the surface horizontal sound speed for the former or the vertical sound speed for the latter. For the DOT path, the refraction correction is also applied, and allowance is made for the 8-ms delay for a DOT to respond to an interrogation. Thus, the ping residuals ($\delta^* - \hat{\delta}$) are computed for each ping within the 5-min window.

An edit window rejects any residual that is unacceptably high, thereby eliminating false or wild-point detections. Standard linearized least-squares methodology^{6,7} is then used to compute a correction to the solution estimate by minimizing the sum-of-squares of the residuals. Solved for are the (x, y) positions of each buoy (at the midpoint of the 5-min window being processed), their (x, y) velocities, and updated values for the vertical and horizontal sound speeds. New residuals are calculated on the basis of the updated solution estimate, and the entire procedure is iterated until convergence criteria have been satisfied, at which time uncertainties are also computed. The sliding 5-min processing window is advanced by 1 min to generate the next solution, and successive solutions are produced until the end of the ping file is reached.

The edit window that rejects invalid pings during each iteration is a function of the standard deviation of the set of residuals, and as such decreases as the solution improves, in effect keeping only the more accurate ping detections. After the start-up phase, in which DOT pings alone are used to obtain the very first set of position solutions, the beginning estimate for each successive solution becomes the answer from the previous 1-min point, extrapolated forward in time by the respective (x, y) velocities. The PMP software determines when insufficient ping data exist to solve for any unknowns, and in this instance estimated solutions are projected; the next time interval may once again have enough pings to compute a solution.

Some arrays have more than one DOT transmitting the same ping frequency, however. The buoy navigator must deduce which of several DOT's with the same frequency has transmitted a received ping, and the only option is to compare the residual for each candidate and choose the one with the smallest error. This procedure works well if the estimated buoy position is fairly accurate, but the choice is more prone to error if the DOT's in question are

roughly equidistant from the buoy. Fortunately, DOT's with duplicated frequencies are usually widely spaced, and symmetrical placement of these DOT's is avoided within the array.

A buoy navigation control menu enables the PMP operator to accept or override all parameters affecting the buoy navigation process. These parameters include solution window and time increments, convergence threshold tests, edit window and ping-count constraints, and uncertainty limits. The buoy navigation results—representing sets of buoy position, velocity, and uncertainty values at 1-min increments—are saved in a character-format file, which can be printed immediately by the operator and inspected for reasonableness. The menu also offers the option to produce graphs of the solutions. Figure 5, an example of a buoy drift plot, shows the position solutions for one buoy over a 10-min span. Shown in Figure 6 is a PMP graph of all buoy position solutions at one common time, relative to the center of the DOT array. Here, the drift vector represents the average drift of all sonobuoys during the 10-min span.

Impact Solutions

Having solved for a time history of buoy positions during the SMILS test, the PMP must next evaluate the splash table of impact detections and produce solutions

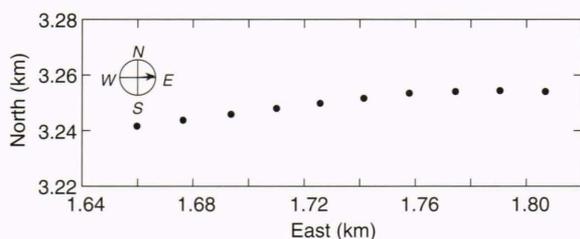


Figure 5. A PMP graph showing the (x, y) positions (relative to the DOT array center) of a SMILS buoy at 1-min intervals. Each plotted point is actually an error ellipse, indicating the uncertainty in the solution. The compass vector indicates average drift direction; the magnitude for the buoy is 0.273 m/s.

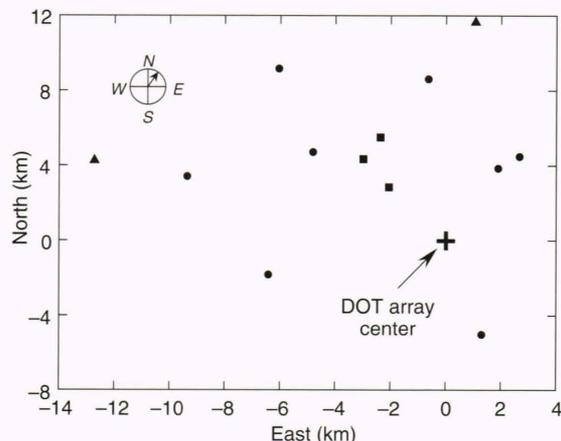


Figure 6. A PMP graph showing position solutions for thirteen buoys in the SMILS pattern, relative to the DOT array center. The compass vector shows that the buoys tend to drift in the indicated direction at about 0.3 m/s. (Squares, air-deployable interrogators; circles, low-frequency pingers; triangles, high-frequency buoys.)

for the time and (x, y) location of each RV impact (system requirements specified that the PMP should be able to solve for up to forty impacts). The problem is essentially a complex sorting task; splash detections for each buoy in the table are scrambled, and a given buoy may hear the splash from a nearby impact before it hears the splash from a distant impact that occurred earlier. Furthermore, the splash table often has missing detections and some false detections. Each impact tends to be associated with several reverberations from the ocean floor, and the preprocessor cannot always reject these detections on the basis of their differing frequency content. Such a high-energy impact also produces a large “bubble” upon striking the ocean surface, and the noise from the collapse of water filling this void can often trigger the preprocessor impact detectors.

Unlike the buoy navigation problem, a goal of the impact solution software was to eliminate the need for any *a priori* estimates of impact locations and times, thereby producing objective solutions that are not influenced by an operator “steering” the answer. Nevertheless, the linearized least-squares technique that generates RV impact solutions must begin with some reasonable estimate. A spurious starting estimate, particularly with many false detections in the splash table, can increase the probability of producing a false solution.

A grid-search algorithm was developed to evaluate the splash table data and identify a series of likely (x, y) target centers for use as impact location estimates. The ocean surface above the DOT array is divided into a grid, nominally 30,000 m on each side, with a grid spacing of 250 m. Each grid point is treated as a potential (x, y) location of an impact. A splash detection time represents an impact time plus the propagation time it takes for the sound to travel to the receiving buoy. If t_j^* represents a splash detection time at buoy j , located at position $[x_j(t_j^*), y_j(t_j^*)]$, then,

$$t_j^* = \hat{t}_0 + \frac{1}{V} \sqrt{[x_j(t_j^*) - x_0]^2 + [y_j(t_j^*) - y_0]^2},$$

where (x_0, y_0) is the location of the grid center being considered, V is the surface horizontal sound speed solved for during the buoy navigation process, and \hat{t}_0 is the impact time.

To evaluate whether a specific grid location is a likely target center, the time for sound to travel from that presumed impact to buoy j can be subtracted from the detection time to arrive at a candidate impact time, given by

$$\hat{t}_0 = t_j^* - \frac{1}{V} \sqrt{[x_j(t_j^*) - x_0]^2 + [y_j(t_j^*) - y_0]^2},$$

where \hat{t}_0 is now the candidate impact time for the current grid center based on splash table entry t_j^* for buoy j . If a similar computation is performed with the detections for all other buoys in the splash table and this same candidate impact time appears somewhere in the table for every other buoy as well, then grid center (x_0, y_0) is like-

ly a valid target location. This description oversimplifies the problem, but essentially an efficient algorithm was developed to apply this approach to every grid center. The result is a ranking of those grid positions for which the most splash detections tend to confirm an impact, within a specified tolerance level. These top-ranked (x, y) positions are used as the starting "guesses" for the next phase of the impact solution software.

The impact solver uses a linearized least-squares procedure to attempt to produce a valid impact solution based on every detection time in the splash table. Each splash detection, in turn, is paired with one of the (x, y) guesses from the grid search, thereby producing an estimated impact location and time. Using this seed estimate, residuals are computed for every detection in the splash table. Each residual represents the difference between the expected time of arrival of a splash (based on the seed impact estimate and the known buoy position at the time of detection) and the real splash time in the table. A selection algorithm picks the smallest detection residual from each buoy, rejecting any that are larger than an edit window. Again, the iterative, linearized least-squares methodology refines the solution estimate to best fit these selected detections. The updated estimate is used to recompute residuals, and the select/solve process is iterated until convergence is attained. The edit window diminishes (the minimum size is constrained) as the standard deviation of the residuals decreases, thereby rejecting more and more inappropriate detections. The solution attempt with the current seed detection and (x, y) guess is aborted if fewer than four detections fit within the edit window, or if the (x, y, t) solution is adjusted to an unreasonable value.

The resulting answer is tested for validity by checking that (x, y) and time uncertainties are within specified thresholds and that the solution has been based on a required minimum number of detections. If these tests are not met, the software rejects the solution and moves to the next (x, y) guess or the next seed detection from the splash table. The detections used for any valid solution are flagged in the table to disallow their use in a subsequent solution. Thus, the PMP processes detections in the splash table until all have either been tried with every (x, y) guess or used in a valid solution.

The final step is to check the resultant table of impact solutions and remove any that may represent a bubble collapse. This event appears as a duplicate solution occurring within a small range and time increment from a previous solution. The final RV impact solutions, uncertainties, and error ellipses are saved in a character-format file, and menu options allow for printing and graphically displaying the data. Finally, the PMP software computes the total geodetic uncertainty associated with each impact, combining relative uncertainty from the least-squares solution with known uncertainty in the surveyed DOT coordinates, which provide the geodetic reference.

The impact solution control menu also allows the operator to accept or override all impact processing parameters, including grid-search controls, sorting and edit window constraints, criteria for accepting a solution as valid, and criteria for rejecting solutions as bubble collapses. Another option allows an operator to edit the splash table interactively to enter or delete a detection

time (presumably after having examined, using the preprocessor, on-screen graphs of the digitized raw impact data). Because the PMAS is designed to be totally automated, this edit capability is included only as a back-up option and should not be needed.

SYSTEM PERFORMANCE

The PMAS system has been delivered to the sponsors at Wright-Patterson Air Force Base and has entered the final testing phase. Once the preprocessor is used and the input data files are transferred to the PMP, about thirty minutes of processing time are required for an end-to-end run. Thus far, operating experience has shown that buoys can be navigated with $1 - \sigma(x, y)$ uncertainties of typically 1 to 3 m, and often under 1 m. In general, impact solutions have uncertainties of 1 to 4 m in the x and y positions, and less than 2 ms in time (these are relative uncertainties, not including geodetic uncertainty in the reference DOT array). The buoy navigation software has been shown to work well, even in a DOT array in which only three DOT's had unique ping transmit frequencies. The impact solver software, with its grid-search technique to identify (x, y) target estimates, has worked well as long as the false alarm rate for preprocessor splash detections remains below roughly 100%.

A "Phase 2" test of the ARIA/SMILS involved deploying a pattern of buoys over a DOT array and simulating impacts with explosive charges dropped from the ARIA as it flew a north-to-south route through the buoy pattern. Nine charges were dropped, but two were believed to have failed to detonate. Although the acoustic signature of these charges was markedly different from that of true RV impacts, and the preprocessor had to be tuned to produce an acceptable false detection rate, the PMP was able to solve for the seven simulated impacts. No "ground truth" was available to evaluate the solution accuracy; the results, however, were consistent with predicted impact locations based on aircraft logs. A PMP mission overview plot is shown in Figure 7, which gives

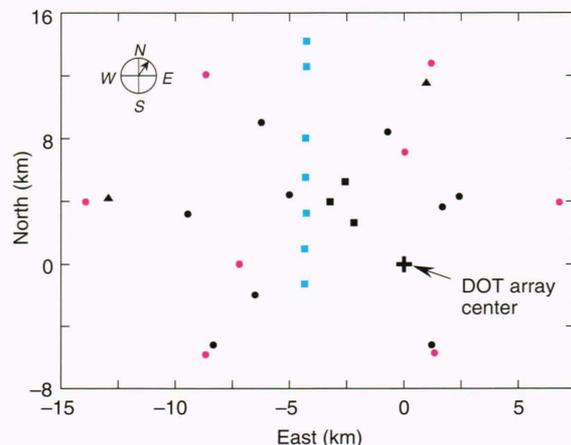


Figure 7. Plot of the results of a Phase 2 test of the PMAS. Shown are the location of the DOT array center and all DOT's in the array (red circles), the position of all SMILS buoys (black) at the time of the first impact (shown in Fig. 6), and position solutions for seven simulated RV impacts (blue squares). (See Fig. 6 caption for buoy symbols.)

a bird's-eye view of the Phase 2 test. The plot shows the DOT array center and (x, y) location of each DOT, the position and type of each buoy in the SMILS pattern, and the position solutions for seven simulated RV impacts.

A PMAS design goal was to require minimal expertise of Air Force personnel running the system. The menu-driven interface and defaulted control parameters have proven to work well, and Air Force operators have rapidly become proficient at overriding menu parameters as required to handle unusual processing situations. Thus far the PMP has met all system requirements, and we anticipate that final Air Force tests of the ARIA/SMILS system will demonstrate PMP readiness to provide operational support for ballistic missile scoring exercises.

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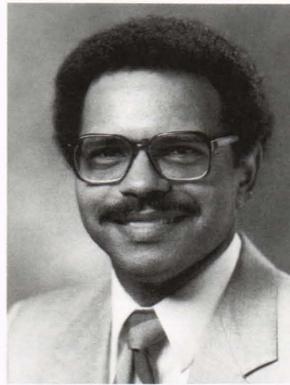
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