Using ArcView / ArcGIS for Near Shore Maritime Operations

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ABSTRACT

With the focus of critical U.S. programs for Homeland Security (HLS) and Homeland Defense (HLD) applications, the need for a GIS based mapping tool for the near shore land and maritime environments is now of paramount importance.

Standard ArcView/ArcGIS software has limited capabilities in the near shore ocean environment. Their weaknesses include plotting near shore bathymetry and geoacoustic, sound speed, current, sediment transport, and weather parameters. In addition, ArcView/ArcGIS are especially weak in plotting and updating real time ship tracks critical to HLS/HLD applications. And the plethora of available survey data available require a great deal of pre-editing for applications in specific areas—lengthening the time before analysis can be performed.

However, the paper shows that capabilities in the application of ArcView/ArcGIS to the near shore maritime domain may be advanced. The results of some of these advances are given in the paper.

INTRODUCTION

To meet the new unconventional threat to the United States homeland, the military has developed a defense philosophy called *Anti-Terrorism/Force Protection* (ATFP).

Shielding us from this new threat may require another high technology version of the sentry—who has the ability to see, reason, smell, hear, infer intent and do any number of other things humans do easily but which are difficult to duplicate with a machine or computer program. The foot patrol sentry cannot be everywhere so he sits in a command and control (C2) center in front of monitors displaying real-time sensor data. And if he can extend his senses to the water, around a perimeter, on the land, in the air, and do it in a way that duplicates, as close as possible, the scene he would experience if he were actually there, he has in effect multiplied himself—kind of like becoming several sentries in one. Such a multi-sensor ability suggests the need for a data fusion system and a geo-spatial display that incorporates many different sensors and threat modes.

A single command center that receives data from multiple sources is a valuable asset, but there is a need to first fuse like-data and then integrate it: take it from the various point sensors that are displayed on black boxes in a C2 center and put them onto one display. This process creates the desired analysis tool for threat assessment. In other words, data fusion, along with single-site data integration is an analysis tool that improves the decision soundness of a local homeland defense manager. Toward the goal of developing such an analysis tool, the authors have designed and built a data fusion system that may be used as a data source for a data integrator. The ideal tool for integrating and analyzing fused data is a Geographic Information System (GIS) that can overlay *layers* of different sensor types onto a single geo-spatial display. There are several Commercial off the Shelf (COTS) software available that may be used to *layer* sensor data. One of the most well known is ArcGIS.

The capabilities of ArcGIS applicable for such a system are: 1) an easily acquired and relatively economical computer system and geo-spatial display, 2) layering that gives control of the degree of complexity in a defense scene to the GIS analyst, 3) analysis that shows the spatial relationship between objects and events in 2D and 3D and 4) real-time plotting.

In order to explain the requirements for a Homeland Defense-GIS (HLD-GIS) system, we will first describe the threat; next summarize our solutions to date through the implementation of a proprietary data fusion system; and finally discuss the advantages and utility of adding ArcGIS to enhance the capabilities of the data fusion system.

BACKGROUND

On October 12, 2000 a few men in a motorboat incapacitated, and almost sunk, a United States warship: the U.S.S. Cole, and killed 17 men (Fig. 1). On October 6, 2002 a few men in a motorboat incapacitated a merchantman: the French tanker Limburg carrying 397,000 barrels of crude oil (Fig. 2). And on September 11, 2001 nineteen men in four airplanes attacked the World Trade Center, and Pentagon and 3,000 people died. These events demonstrated that persons could successfully attack the country, and its military assets, with low-tech weapons and do it with virtually no warning. The U.S. was well equipped to fight a traditional military enemy but was not prepared to prevent an attack on home soil. The military was focused on high technology solutions to complex battlefield problems, and blindsided by simple human intelligence—and passion. The "guidance systems" the enemies of our country used were simply their brains. It became clear that our military and naval units were also vulnerable at home and abroad and that there needs to be a way they can monitor the complex environment around them and identify potential lethal attacks from non-traditional threats in the future.

Fig. 1 U.S.S. Cole entering a floating dry dock with a hole in its side. *(Internet Photo)*

Fig. 2 French tanker Limburg on fire near Yemen *(Internet Photo)*

GOVERNMENT INTEREST

Recently the Naval Sea Systems Command issued a memorandum for distribution entitled *"Call for Information on Antiterrorism Capabilities"*. That memo announced that the "Navy has formally established *Afloat and Ashore Antiterrorism Programs* to develop, procure, and sustain enhanced Navy antiterrorism and force protection capabilities."[1] The memo also said the Navy must collect "information on available technologies or capabilities…" On 7 April 2004, SPAWAR sent out an email calling for a submission of technology for consideration in aspects of ATFP. Among the technologies of interest to SPAWAR are those that can address "*Wide Area Alert/Notification", "Early Warning", "Waterside Protection"* and *"Security Surveillance".*

These factors—threat and government need—suggest a comprehensive utilization of sensor assets.

SENSORS and INTELLIGENCE

The data necessary for surveillance and threat assessment, early warning and waterside protection, must come from sensors and intelligence.

Applicable sensors would be sonar arrays placed on the bottom of the ocean near shore, radar, national sensors (satellites), optical (visual and infrared (IR)) such as cameras and buried fiber optic cables for barrier intrusion protection, and nuclear/radioactive and bio-chemical sensors that measure the amount of toxic aerosols present. Data from these sensors generate point or positional information and would be (1) direct inputs *to* a data fusion system and/or (2) indirect inputs *through* a fusion system to a GIS.

Intelligence information, such as the Navy's Meteorology and Oceanography (METOC) intelligence or data from the Joint Maritime Information Exchange (JMIE), may also be integrated with sensor positional data providing the intelligence data also comes with position even if it is also distributed (has shape). And it would be advantageous to have a separate input from a local Marine Exchange (MX) that monitors commercial shipping in to and out of major ports as a backup source. Any other intelligence data that contains positional and distributed information could also be added to a GIS display through the data fusion system.

Fig. 3 shows an example of the placement of sensors around Camp Pendleton including the ocean. The example should not be taken as a statement that there is a known threat, nor are the indicated sensor placements real.

Persons may enter the area from a remote location in order to infiltrate the base. Intruder detection is important in this case. Optical and IR sensors can play a part in detection with audio detectors giving additional support.

Ashore, an automobile or airplane may be used to spread bio-chemical toxins in the area. In such a case, however, instant detection and identification of a threat vehicle is virtually impossible since ground traffic is commonplace. However, it would be vital for toxins released from vehicles to be detected early and their spread predicted. This requires a combined input from bio-chemical sensors, spread algorithms and METOC intelligence.

Or a seaward threat could come from a merchant ship or an Automated Underwater Vehicle (AUV) launched from a merchant ship. Fishing boats, which are virtually undetected by radar from land until they are close to shore[2], may be the platforms from which underwater (u/w) swimmers could be deployed toward the military base, oil platforms or against a naval ship in port. One of the most critical areas for intruder

[1] Department of the Navy Memo dated March 23, 2004
[2] Inferred from private discussions at the Los Angeles Marine Exchange

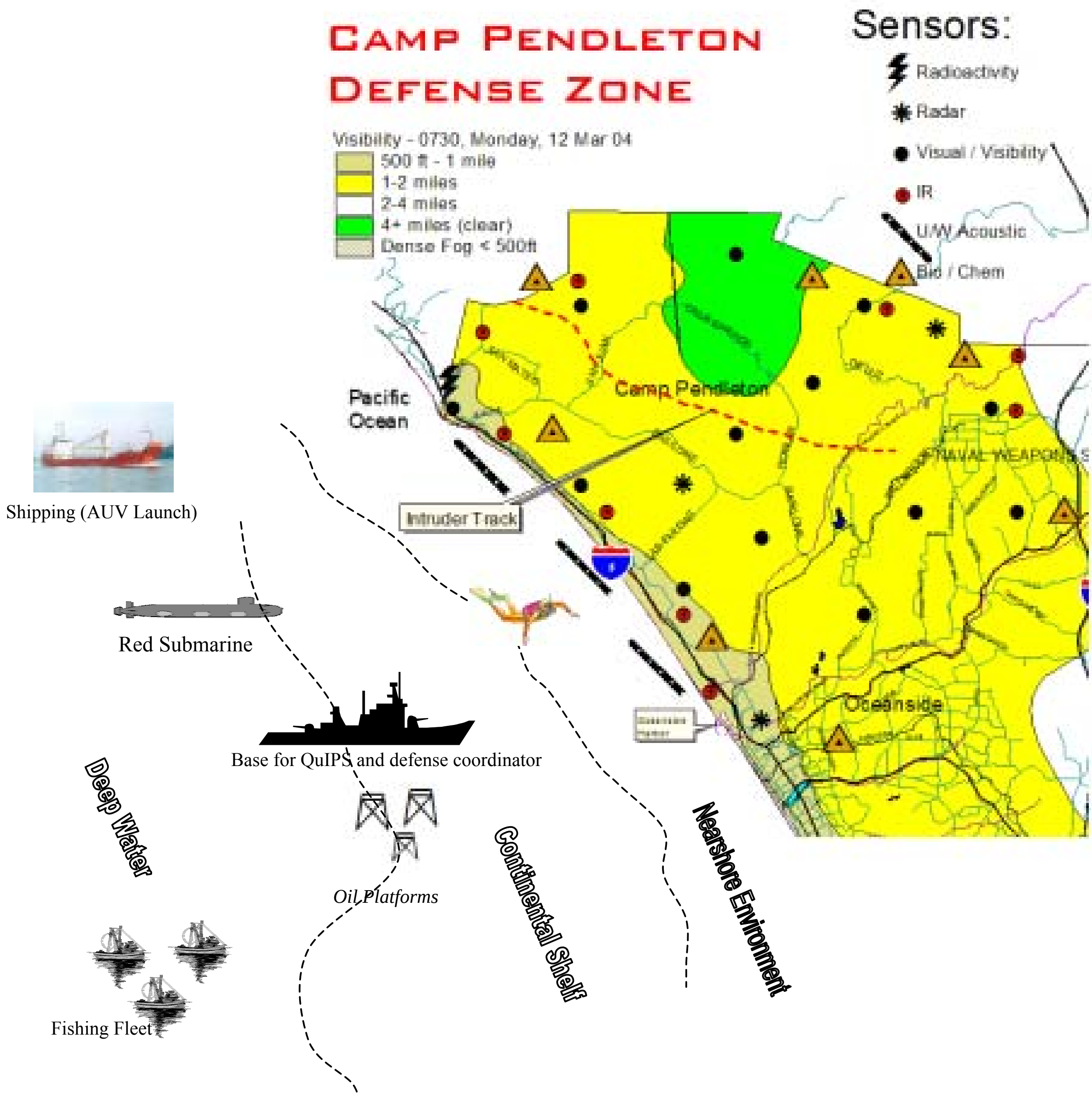

Fig. 3 Possible threat and sensor placement scenarios for one military base.

detection is underwater nearshore. u/w sensors would necessarily require acoustic devices that use sophisticated data processing algorithms to enable detection. Such algorithms are needed because of the complexity of sound path arrivals from source to receiver in shallow water. Therefore, raw acoustic data could not be delivered to a GIS without pre-processing.

In summary, an unlimited number of ways to detect and identify multiple mode threats exists.

QuIPS

In conjunction with the Coalition Warfare Program, and in line with the current interest of the US Government, the authors have designed and built a detection, tracking, locator and fusion system known as the Quiet Interlude Processing System, or QuIPS, using open source software on a computer with a Linux cluster. The rationale for such a system is because "no automated data fusion system exists in the nearshore environment to detect, track, classify, and neutralize the significant threats capable of delivering Weapons of Mass Destruction to U.S. and Coalition Forces worldwide, DoD and USCG nearshore bases worldwide, nearshore US civilian population centers, or US offshore critical infrastructure."[3]

QuIPS hardware is designed to accommodate multiples sensors and is expandable to meet any processing power required. The five functional modules in QuIPS are (1) sensor algorithms, (2) runtime software, (3) relational database, (4) visualization geo-display and (5) 802.11 QuIPS COM. One current QuIPS hardware set includes a chassis with six 1U boards each with two 2.6 MHz Pentium IV processors (12 in all), a monitor, a keyboard, and a joystick.

Some of the features of QuIPS are high fidelity RF propagation models, a 4D visualization display that shows geo-spatially and temporally distributed data in 3D, shallow-water acoustic beamforming algorithms, acoustic data fusion algorithms, non-acoustic data fusion algorithms, and weather and bio-chemical spread and other models.

For example, QuIPS sensors will do underwater detection and create a trace on a Broadband Correlogram or a trace on a Narrowband FIM-LOFARGRAM with bearing time-tracks. Or the QuIPS 4D video display (Fig. 4) —a Compressed ARC Digitized Raster Graphic (CADRG)—can be used to "fly" to an area to show any 3D distributed phenomena in real-time, such as a gas cloud or fog, and the area selected in the 4D display would be shown in another 2D layered GIS display down the line.

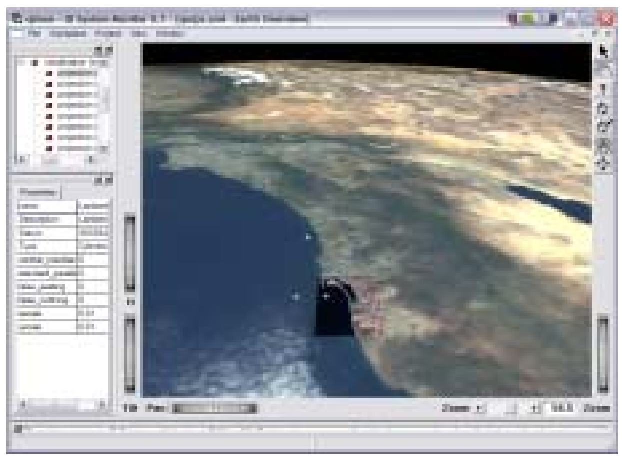

Fig. 4 4D CADRG displayed on the QuIPS monitor

In Fig. 3 the QuIPS platform resides aboard a naval ship surrounded by possible threats—although QuIPS could be placed anywhere: ashore or afloat.

QuIPS OUTPUT to GIS

Generally GIS systems have been used to show relationships between spatial features and historical changes in the environment and how those changes may impact a region: like the long-term effect of fire on animal habitats or the assessment of damage from a man-made or natural disaster. However, the HLD-GIS system would not be designed to assess or analyze historical data or its impact on the environment. Tools, such as the CATS disaster analysis system from ESRI and SAIC, already exist to do that. The different approach to analysis in an HLD-GIS

[3] Wilson, James H., *QuIPS System Description and CONOPS with and without Integration into the Mobile Inshore Undersea Warfare (MIUW) Program.* A Neptune Sciences presentation. April 2004.

system is that it looks forward, not backward (not historically) by displaying the effects of real-time changes in the short term and how those changes impact security in the present or near future. The HLD-GIS receives data from multiple sources with intelligence, processes it and sends all that data to a layered GIS display. Therefore, an HLD-GIS-QuIPS system becomes a real-time spatial threat analysis system.

Raw data arriving at the QuIPS are fused and stored in a relational database (MySQL) for instant retrieval and, when retrieved, combined with a visual dynamic model. The plethora of outputs from such a detection and fusion system demands a multi-layer geo-spatial display for the C2 watchstander. The utility of such a display is that it combines all the data into one picture and thereby presents a tool to the human that allows him to do what he does best: visually integrate movement, infer intent, and thereby predict a specific target to which an intruder is headed—a capability often beyond a computer programmer to automate—even though there seems to be no end in trying to automate everything in the industry.

ArcGIS will integrate different types of data and place them into their own layers: real-time sensor layers, a real-time shipping layer, intelligence layers, edited bathymetry layer, real-time meteorological intelligence layer, and standard basemaps offered by the Department of Defense (DoD), or other government and commercial vendors. Therefore, the HLD-GIS-QuIPS system gives the watchstander the advantage of an integrated view of the relationship between a potential threat, the land, the weather, and the proximity of the potential threat to restricted or populated areas.

In Fig. 5 a 2D National Imagery and Mapping Agency (NIMA) Digital Navigational Chart (DNC) represents one possible output to a layered GIS, even though it is also displayed on the QuIPS system. The NIMA DNC chart is not the end product itself; it is only one layer, or one of several different types of maps/charts that may be available to the GIS.

Fig. 5 A NIMA DNC chart representing one layer of a 2D GIS.

The output from the QuIPS system comes in two forms: points and polygons, or tracks and geo-spatially distributed data. One typical fusion data point product is remote (e.g. satellite) *and* local radar (e.g. at Camp Pendleton) contacts of ships. Such contacts, for example, could fill gaps in coverage between L.A. and San Diego.[4] These time series contacts become tracks with Latitude/Longitude coordinates.

Examples of other tracks are broadband correlator tracks fused from u/w acoustic data; narrowband beamformer tracks fused from several frequency bands; or matched phase matched field processor tracks from several frequency bands. Other QuIPS track data may be produced from the fusion of radar and JMIE tracks and attribute data. Still other track data may be from communications intelligence (COMINT), or the automated information system (AIS). These outputs are available for inclusion into ArcGIS. Each type of data or type of source may be designated for a unique data layer.

Distributed time series data gives the shape of a 2D object like the extent of fog or gas clouds in real-time. Distributed data may also be "fixed" imagery that changes very slowly: from snapshot to snapshot—from satellite pass to satellite pass.

[4] W. P. Jameson. That gaps exist is from private discussions at the L.A./L.B. Marine Exchange (MX)

By combining the target/contact outputs from QuIPS into a single picture, the GIS facilitates the decision to kill, investigate or ignore a potential target. Fig. 6 illustrates the overall functionality of the system and shows QuIPS receiving data from multiple local sensors as well as remote sensing sources. Local sensor data is transmitted through QuIPS COM using 802.11 long-range broadband wireless communications to tie the local sensors in the field to the fusion system in a C2 center because landline communications can be unreliable. As the figure illustrates the critical decisions are made at the GIS station.

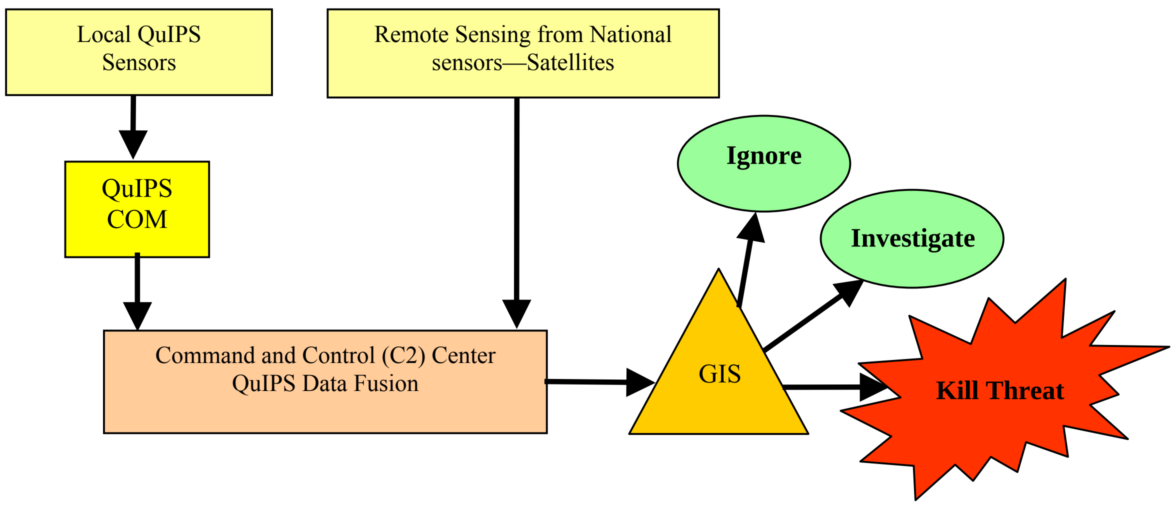

Fig. 6 Local Sensor to Shooter Connectivity using QuIPS-COM

ADDITIONAL NON-QUIPS DATABASE FOR COASTAL REGIONS

QuIPS supplies the data to the HLD-GIS system with the exception of an edited regional database like bathymetry. There is a lot of bathymetry data available but in single-track surveys across large expanses of ocean. To combine all that data for only a single coastal area may overwhelm a GIS, besides being unnecessary. Therefore, it is better to build a module to edit data with latitude and longitude limits and concatenate the residuals from the various tracks. For example, thousands of lines of survey data from many different ship tracks that run from the mid-Pacific up to the San Diego coastline are available, but most of the data are unnecessary if one is only interested in the San Diego area. And since the ATFP Maritime Zone (MZ) extends to 60 nautical miles seaward from a defense area[5] there would be no ambiguity about data (lat/long) limits that can be put into the data editing module.

TRACKING ANALYST

Tracking Analyst is one of the extensions available for ArcGIS. It is designed as either a historical or real-time tracker. Data coming into the ArcGIS computer continuously adds records

[5] *Advanced ATFP Technology based on the Quiet Interlude Processing System.* Presentation at Camp Pendleton by Robert Clark, Capt USN, Jerry White, CDR USN, Ann Vanhaaren, SPAWAR 05 and Dr. James Wilson, Naval Post Graduate School. March 2004.

to an attribute table that is being read by the Tracking Analyst extension. This data may be input into the computer's USB port. Each type of data: radar, sonar, etc. would be tagged with a string that uniquely identifies the sensor and sensor type. Each sensor source is in turn associated with a unique symbol that is plotted in near real-time giving the watchstander immediate information of which sensors are tracking the target. It is important to know which kinds of data the target is generating since this alone may affect the watchstander's ability to analyze the threat. For example, a near-shore target could be submerged or on the surface. Submerged targets would be detected only acoustically, whereas surface targets could be detected acoustically, visually or by radar. Therefore, it is likely that two or more sensors may track a single contact but represent it graphically as two or more side-by-side contacts. This feature increases the confidence in verification and identification.

Fig. 7 illustrates the general input and output of the HLD-GIS-QuIPS system using the tracking analyst extension. It shows two inputs from two different Maritime Exchanges (MX) as they transmit their contacts on two ships to the C2 center. There are three local radars (R1, R2, and R3) tracking the same contact as that of MX1. A fourth radar, R4, is tracking the same contact as MX2. The MX data is tagged as such and placed into the attribute table of the tracking analyst as two separate targets. The fused radar data is tagged as Radar and placed into the tracking analyst as a single target, and the fourth radar is tagged and placed into the tracking analyst table as a separate target. The other contacts follow the same type of reasoning.

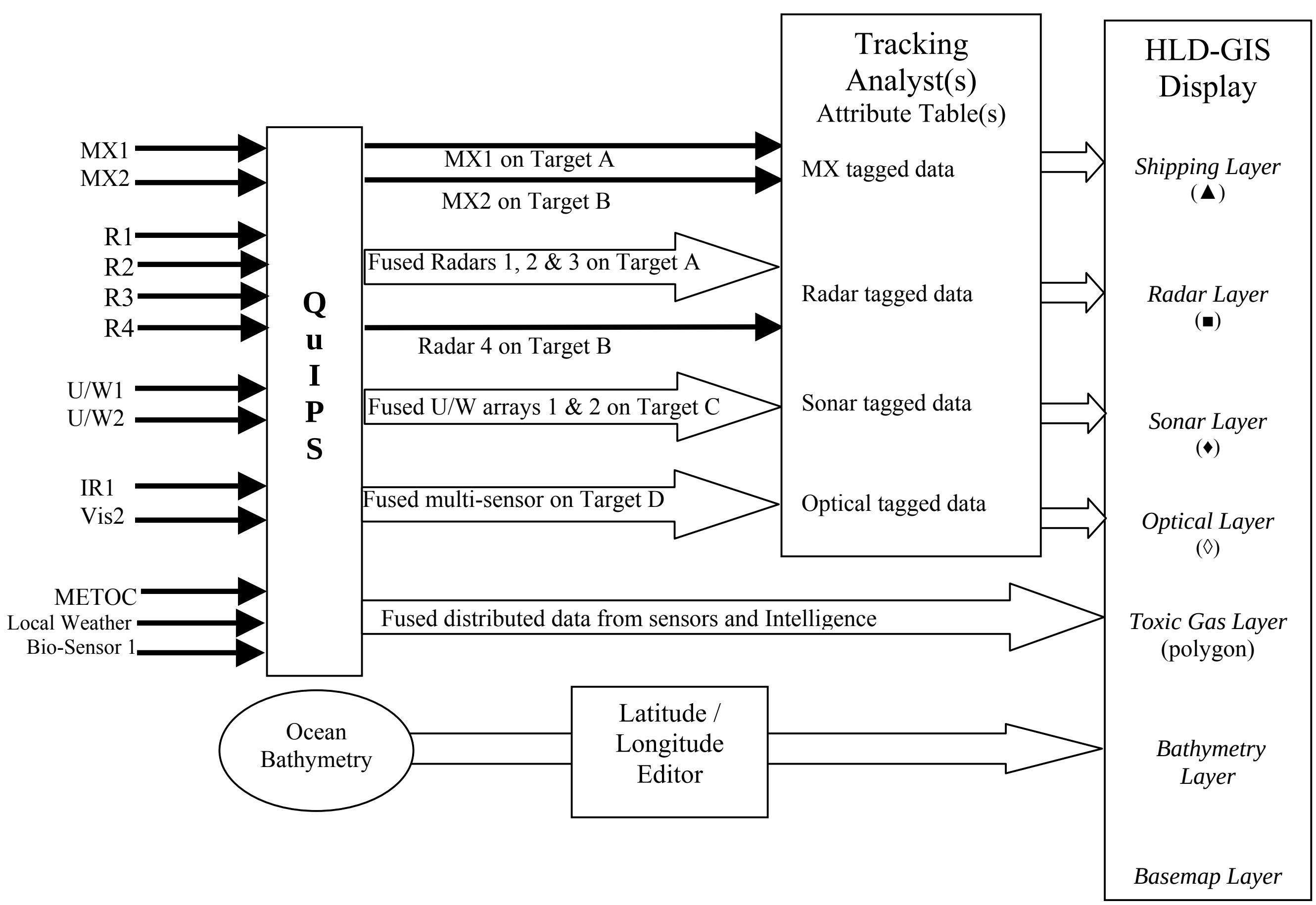

Fig. 7 HLD-GIS-QuIPS system incorporates tracking analyst

CONCLUSION

A data fusion system has been built that meets the need of the military to fuse early warning sensor data in order to enhance the liklyhood of detection for the purpose of protecting ashore and afloat military assets—especially ships as they sit in harbors, near-coastal assets like oil platforms and coastal military facilities. The capability of ArcGIS to display multiple layers may be used as a data integration tool for the output of an existing data fusion system. Such an overall system that marries the two technologies enhances the defense manager's ability to analyze, investigate and if necessary, prosecute a threat in real-time before damage is done.

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