

## **Resolving Radar Ambiguities: A 3-D Look at EW Analysis**

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### **Visualizing Abstract Data**

Three dimensional graphical representations of abstract data can be a powerful tool for analysis and reporting. Complex information can be conveyed in an intuitive, easy to understand, easy to use manner. Using shape, color, position and motion, hundreds and thousands of items can be shown on a single screen. A traditional database reporting system with a hundred screens of data can be replaced with a single 3-D screen. Because the information is presented visually, efficient innate human capabilities can be used to perceive and process data. Orders of magnitude more information can be processed in a few minutes.

Information displays have moved beyond 2D bar charts, line charts and pie charts, and beyond

the interactive 3D scatter plots and contour plots of statistical and scientific visualization. It is now possible, on an inexpensive workstation, to build, display and have updated in real time, visual scenes comprised of abstract 3D geometrical forms. The viewer's point of view can move through these 3D scenes, and the objects themselves can move within the scenes.

These new kinds of 3-D displays are only possible because graphics hardware has become more powerful and more affordable. Today's Pentium Pro machine is as powerful as a 1991 top-of-the-line Silicon Graphics VGXT.

Of course, military and industrial simulations have long made use of computer graphics hardware in applications that portray realistic visual scenes showing tank combat in urban centers, or merchant marine vessels docking in busy harbors. However this same hardware technology can be used in management and knowledge worker tasks. "Information animation" is the application of this level of computer graphics power to data intensive analysis and decision-making tasks where the 3D landscape comprises numerical and text data.

### **Analysis of Electronic Warfare (EW) Data**

Radar emitters are characterized by parameters such as radio frequency (RF), pulse repetition interval (PRI), pulse width (PW), scan period, and modulation characteristics. These are multi-dimensional characteristics or parameters, which when combined define emitter operational parametric modes. The complexity of the radar system will determine the number of parametric modes required to represent all of the radar's operating modes.

EW systems are designed to intercept and identify emitters by measuring their signal characteristics (operational parametric modes) and matching this data with EW mission library entries which contain known emitter operational parametric modes.

EW data describing emitters is maintained in libraries. There are master libraries containing the universe of emitters and threat libraries for particular battle theaters. These large and complex libraries need to be created, maintained, analyzed and then used. For example, the EW data in these libraries are analyzed to create appropriate mission libraries to support various EW systems such as radar warning receivers (RWR), electronic support measures (ESM), and electronic countermeasure (ECM) systems.

In the battle theater there may be hundreds of active emitters. Further, each emitter can have hundreds of different "modes" with each mode having its' own RF, PRI, PW, etc. This presents an extremely high density data environment within which to work. Prior to a military operation in the field, EW equipment needs to be programmed with a mission library, i.e. a prioritized list of emitters, and their corresponding operational parametric modes. These are the emitters likely to be encountered on the mission. One of the problems associated with creating mission libraries is the limited subset of operational parametric modes which can be programmed into EW equipment. Another area of concern is the ambiguous nature of the operational parametric modes. There are overlaps, so that, for instance, a target acquisition radar can look like a navigation radar ... sometimes. The EW analyst is faced with the formidable task of selecting the appropriate mode data to represent selected emitters and reducing, if possible, the ambiguities which exist between these emitters. Therein lies the problem that visualization can help solve, because it takes human interpretation of complex multi-dimensional data to decide on the optimal definition of the mission library.

### **Ambiguity Analysis**

One of the common tasks for analysts maintaining reprogrammable mission libraries is the optimization of the emitter parametric mode definitions. Depending on the EW system capabilities, the parametric mode definitions of a particular radar can be minimized by combining modes where specific parameter ranges or associated modulations cannot be distinguished by the EW system of interest.

The problem for an EW analyst is that there are ambiguities, or overlaps, among the emitter modes, and it requires data intensive human interpretation and decision-making to resolve these ambiguities. Of particular concern is the case where parametric modes are ambiguous between different emitters. In this situation, an EW system may identify intercepted data as two or more different emitters. Ambiguity between emitters presents a problem to the user, especially if it exists between a friendly emitter and a high-priority hostile emitter.

To evaluate the usefulness of visualizing emitter mode parameters in a 3-D space, a prototype was built using a commercial off-the-shelf information visualization software tool. The system displays hundreds of modes, and highlights ambiguities, in an animated multi-dimensional space.

It supports user interaction to analyze the space, and to find and resolve ambiguities. The ambiguity analysis prototype provides the analyst with a tool to visually interpret the parametric mode data and quickly identify the key ambiguous areas.

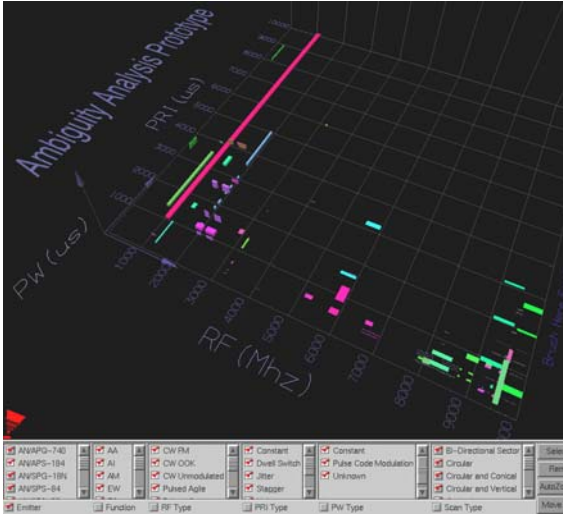


Figure 1. Overall view of ambiguity analysis visualization tool with multi-dimensional parameter space and control panel at bottom.

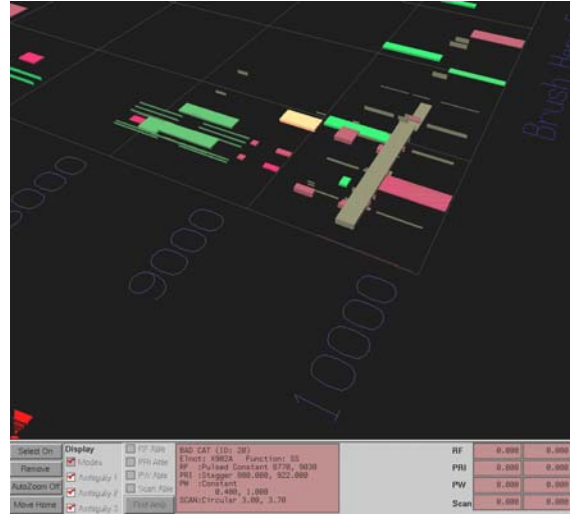


Figure 2. Zoom in to a portion of the workspace showing a close-up on several emitters.

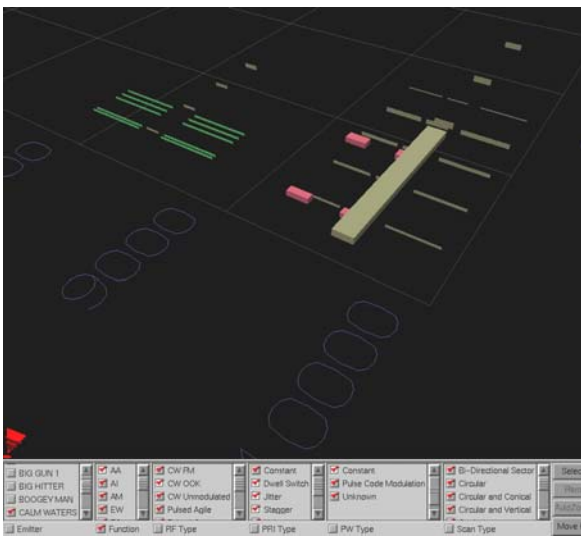


Figure 3a. Emitters may be searched, selected and then toggled on and off.

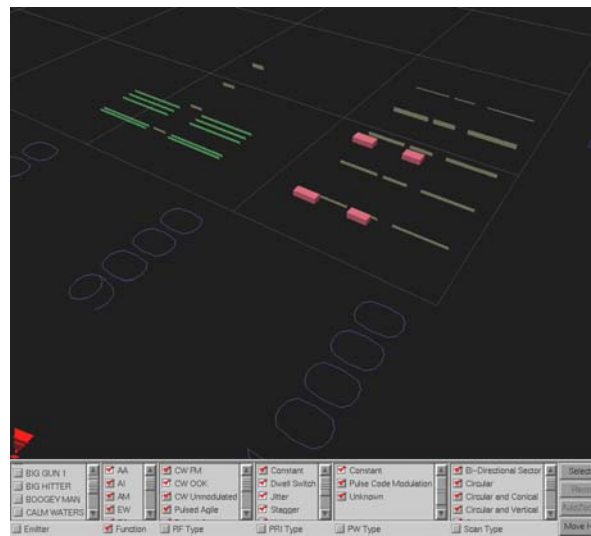


Figure 3b. One emitter toggled off.

Emitter mode data is presented in a 3-D landscape which can be viewed from any perspective. It is also possible to zoom in to any part of the landscape. The three primary axis displayed are RF,

PRI and PW. The PW axis can be toggled to display scan period. Additional dimensions are provided by color, for example, to show emitters or emitter function. The result is a display of colored cube-shaped objects.

Many interactions are provided. For example, users can click on any cube to reveal detailed numerical / text information associated with that specific emitter mode. The measurement capability and specifications of various ESM systems can be displayed in context in the same 3-D landscape. A combination of filters and selection lists allow users to focus on particular subsets of emitters. For example, show me only emitters for certain functions and for certain scan periods, within this range of RF, PRI and PW.

Ambiguities are automatically computed based on a selection of parameters to use for differentiation. The resulting overlaps, and degree of severity in overlap, are then displayed. An analyst can pick one of the overlaps, see all the associated emitter modes and their parameters, and then decide how best to resolve the ambiguity. The display is updated as the analyst adjusts the parametric ranges. These adjustments reduce ambiguity and yield the most optimal parametric ranges for a given mission.

The prototype loads data from flat files. However, the next phase of the prototype's development is expected to include a direct connection to an Oracle database using the commercial toolkit.

In this application, many numerical/text screens of a traditional database reporting system are presented in one 3-D screen. It is a simple, focused and easy to use application designed to provide analysts increased insight into the significance of these complex situations. Insight which can be grasped much more quickly than existing analysis tools.

This example application highlights the requirements for making 3-D graphics work as a new tool for data intensive information analysis and decision-support. Abstract information is shown in 3-D so that users can see more information, more quickly, with more comprehension. Interaction allows users to work with the information and manipulate it as they analyze it. Finally, data integration is also crucial. Military, as do corporate, visualization applications need to be able to access data and analytics wherever they are within an organization. Data integration, interaction and 3-D visualization provide what we mean by information animation.

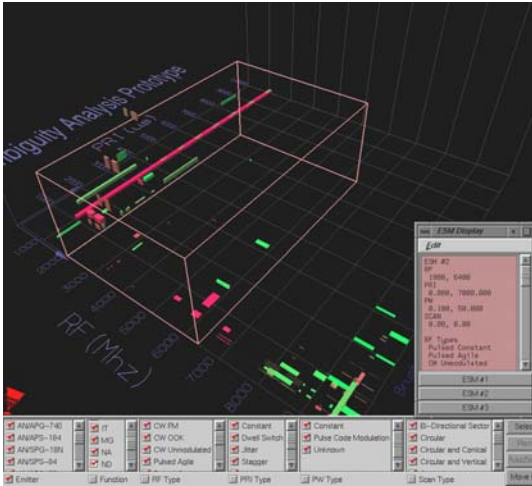


Figure 5. ESM parameters shown in same workspace as the emitters.

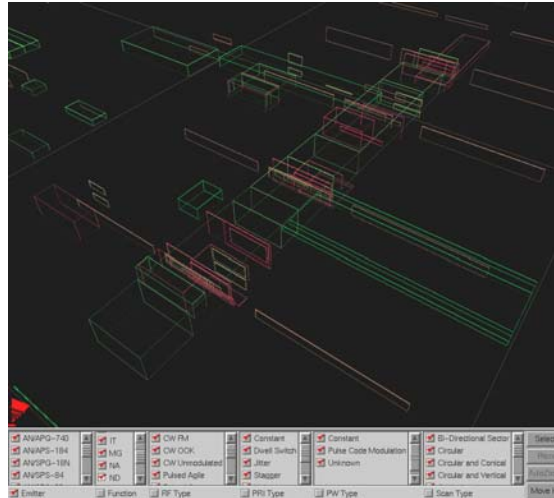


Figure 6. Overlaps in emitters are displayed.

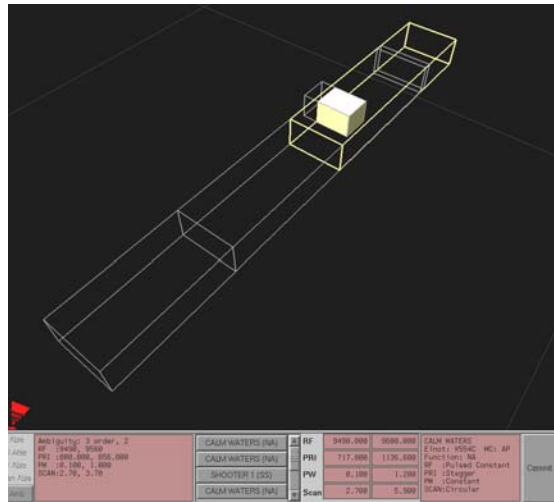


Figure 7. Ambiguities are algorithmically determined and then highlighted in context.

## Other EW Applications

The ambiguity analysis prototype demonstrates visualization capabilities and benefits. Enhancements have been identified and are being undertaken. However, an important conclusion has been that visualization techniques are worth pursuing for a variety of applications.

The following is a summary of potential applications which may benefit from the use of

interactive 3-D visualization tools.

#### ELINT In-Flight / Post Mission Analysis:

Collection systems for electronic intelligence (ELINT) measure and record signals. A 3-D visual interface would allow an operator to see the quality of the received multi-dimensional data, and to optimize system settings, before recording. In addition, an interactive visualization application would allow an analyst to browse a large amount of recorded data to identify significant events and associated data.

#### Mission Intercept / Threat Data Analysis:

The current ambiguity analysis prototype could be modified for use in the field. This would allow fresh mission data to be compared with mission libraries and the central EW database. Mission libraries could be optimized on the spot to correctly identify threat emitters. This would allow analysts in the field to more quickly respond to changes in the EW environment.

#### Mission Flight Planning:

Possible flight paths to reach selected targets could be shown in a 3-D landscape. An overlay of the known emitters could be used to display emitter performance characteristics as the aircraft is flown along the path. Information regarding maximum emitter detection range and lethality could be displayed. The effects of "terrain masking" could be shown. This application would help evaluate what-if flight plan scenarios.

#### Mission Operations Planning:

Military commanders are overloaded with analyzing a vast amount of data to make informed decisions. A visualization application could display "Order of Battle" and "Electronic Order of Battle" (EOB) information in real-time with actual battlefield data. For EW, it would show all emitters of interest with various levels of threat and priority, and allow groups of emitters to be selected for re-programming EW assets for mission operations. In addition, other information of interest such as communication networks and intelligence reports could be presented in context within the visualization application.

The proliferation of information within the "cyberspace" environment has led to the concept of information warfare (IW) within the military infrastructure. This abundance of information often requires quick analysis by military commanders who must maintain situation awareness of the battlefield. EW is only a small subset of IW but represents the complexity of maintaining and

analyzing large multi-dimensional datasets. IW visualization should be as appropriate and valuable as EW visualization.

### **Why Visualize?**

Information visualization is a strategic technology because the amount of data people need to deal with on a day-to-day basis is not getting smaller. For those situations where people need to be in the loop, where human interpretation, judgment and decision-making is required, visualization is the only way to deal with information overload.

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