The USCG

Search and Rescue Optimal Planning System

(SAROPS)

Via the

Commercial / Joint Mapping Tool Kit

(C/JMTK)

Robert Netsch

Department of Homeland Security
United States Coast Guard
Command and Control Engineering Center

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Abstract:

The United States Coast Guard now belongs to the Department of Homeland Security and although busy with new responsibilities, Search and Rescue (SAR) remains a primary mission of the service. Many people equate SAR with daring actions taken by helicopters and rescue swimmers. However, a critical component of the SAR process takes place well before a helicopter can get on-scene. This is the activity of Search Planning. Search planning is largely concerned with the common GIS notion as to "where things are" and contains a wide range of elements pertaining to situational awareness, spatial analysis and drift simulation. Within these areas GIS is key and why the USCG is developing the Search and Rescue Optimal Planning System (SAROPS) with help from the Commercial Joint Mapping Tool Kit (CJMTK).

The US Coast Guard has Command Centers in Puerto Rico, Guam, Hawaii, Alaska, in addition to those all along the coast of the mainland United States. These units are central to a wide range of operations ranging from Homeland Security to Marine Environmental Protection and serve as Rescue Coordination Centers (RCC) in support of Search and Rescue (SAR) operations. Although Geographic Information System (GIS) technology plays a key decision support role in all these functions, this paper pertains to the discipline and technology of SAR planning.

For the most part, September 10^{th} had been an unremarkable day, except that a disturbance had begun to form in the warm waters off Cape Hatteras, NC. The low-pressure cell showed surprising strength in its rapid development from a typical Nor-Easter to a serious hurricane.

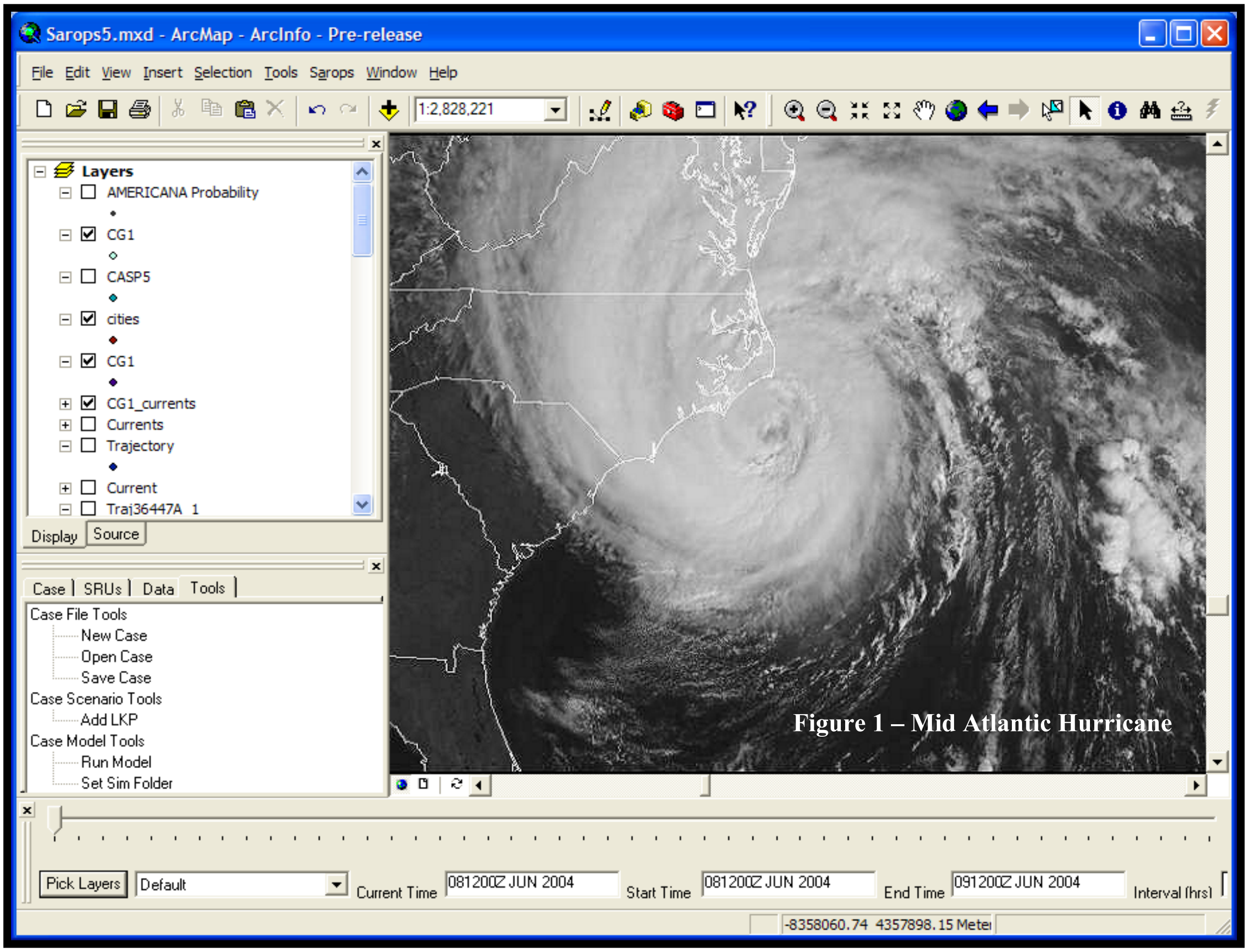

Figure 1 – Mid Atlantic Hurricane

LT Tom Thompson, of the USCG Atlantic Area/District 5 (LANT/D5) Command Center was busy with normal duties and kept abreast of the degrading weather by checking buoy reports, satellite imagery and National Weather Service Marine broadcasts. It was 1630 local time, a C-130 Hercules had just returned from a coastal patrol to AIRSTA E-City and was uploading sightings of interest into the Common Operation Picture (COP) database. The upload had been completed when the Group Cape Hatteras Operations

Officer (OPS) heard from the F/V MARINE; she had just picked up a partial distress call: "MAYDAY - MAYDAY - MAYDAY THIS IS WILLIAM LEWIS HERNDON OF THE S/V AMERCIANA. WE ARE TAKING ON WATER AT POSITION 35-15N …" OPS recorded and forwarded the information to LT Thompson at LANT/D5 who would assume the role of SAR Mission Coordinator (SMC). The area Hi-Sites (Buxton, Oregon Inlet, Cedar Isle) had no record of the AMERICANA distress call. At this point all that was known was the position of the F/V MARINE, the partial coordinates provided by the AMERICANA and the lack of reception at the Hi-Sites. This incomplete distress call was to be the one and only radio communication from AMERICANA. At first glance there wasn't a lot to go on.

Figure 2 - USCG Search and Rescue Aircraft

In 2003 the USCG received a total of over 30,000 calls for assistance. Many of these calls were easily responded to and required nearly no searching. However, 5-10% of the calls became significant SAR events; resulting in action by multiple land, air and sea units. Every day, on average in 2003, the USCG assisted 136 persons in distress and saved 11 lives. An open ocean case with a long drift interval (the time between a search object's Last Known Position (LKP) and the searcher‘s on scene time) can easily require the expenditure of hundreds of search hours and hundreds of thousands, even millions, of dollars. Determining how and where to place the available search assets to maximize the overall effective search plan is the subject matter of Search Planning. The most effective search plan is the one that continuously maximizes the probability of finding the search object as each hour passes. Broken into its most simple form, Search Planning consists of Situation Awareness (ascertaining what happened where and when), Search Object drift modeling (how has wind and water current affected the search object over the drift interval) and Effort Allocation (how best to spread finite aircraft and vessel hours over a search area).

The Search and Rescue Optimal Planning System (SAROPS) is an information system being designed to support Situation Awareness, Drift Modeling and Optimal Allocation of Resources. SAROPS is built upon the Commercial Joint Mapping Tool Kit (C/JMTK), a government initiative to provide enhanced ArcGIS 9 functionality to support Command and Control system development. The open SAROPS architecture can accommodate a wide range of third party extensions to support non-SAR mission areas. SAROPS itself contains an environmental data subsystem built upon ArcSDE technology; a Monte-Carlo particle simulation engine implemented in Java and an extended ArcMap user interface. When deployed, SAROPS will allow the USCG to be even more successful in the timely rescue of lives and property in coastal waters and on the high seas.

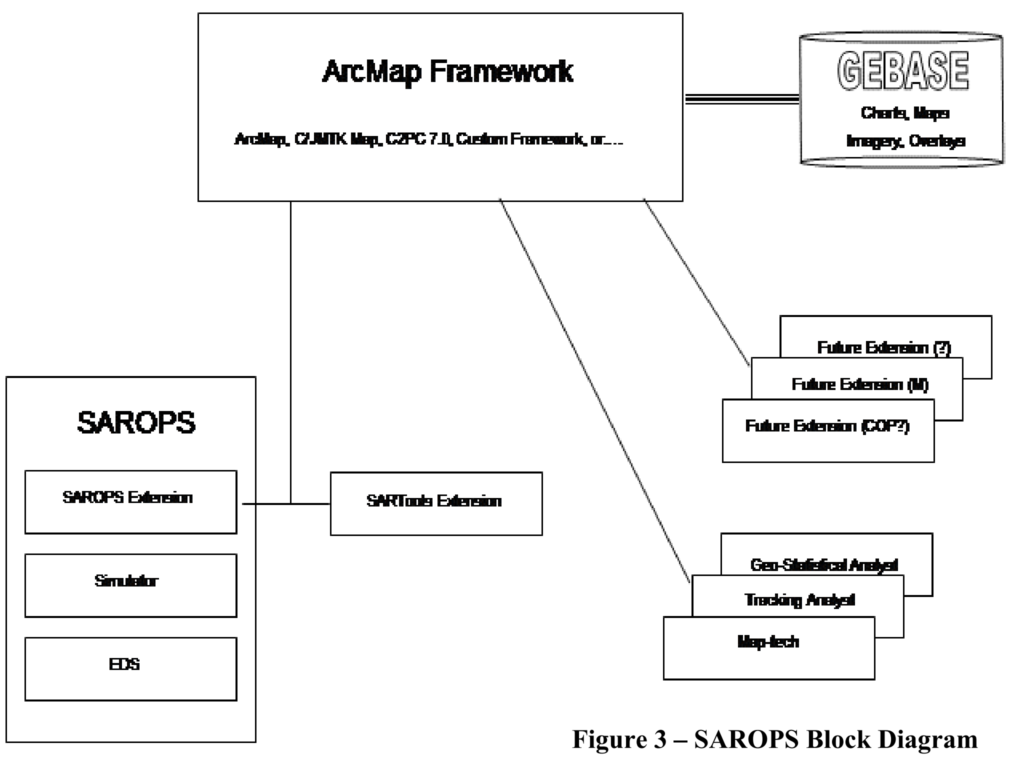

Figure 3 – SAROPS Block Diagram

LT Tom Thompson, a forward thinking GIS enthusiast, knew that overlays on a Geographic Information System are extremely valuable in the analysis of the diverse information received by a SAR Controller. Within minutes he had assembled a Venn diagram style radio coverage graphic to represent where the message was received, Hi-Sites where the message was not detected and the key information contained within the message. LT Thompson selected black range rings to show the nominal coverage of the USCG Hi-Sites. Since these Hi-Sites did not pick up the AMERICANA distress call, it is probable that the AMERICANA was outside of their reception ranges. The maximum range at which the MARINE could have received the distress call was judged to be about 20 NM. This area is depicted with a red range ring, centered on the MARINE. The MARINE range ring minus the Hi-Site Buxton range ring provides a geographic representation of the area from which the call was probably made. Lastly, the AMERICANA provided its Latitude prior to transmission loss. Plotting this parallel of latitude within the remaining red region gives an even better probable location for the source of the distress call.

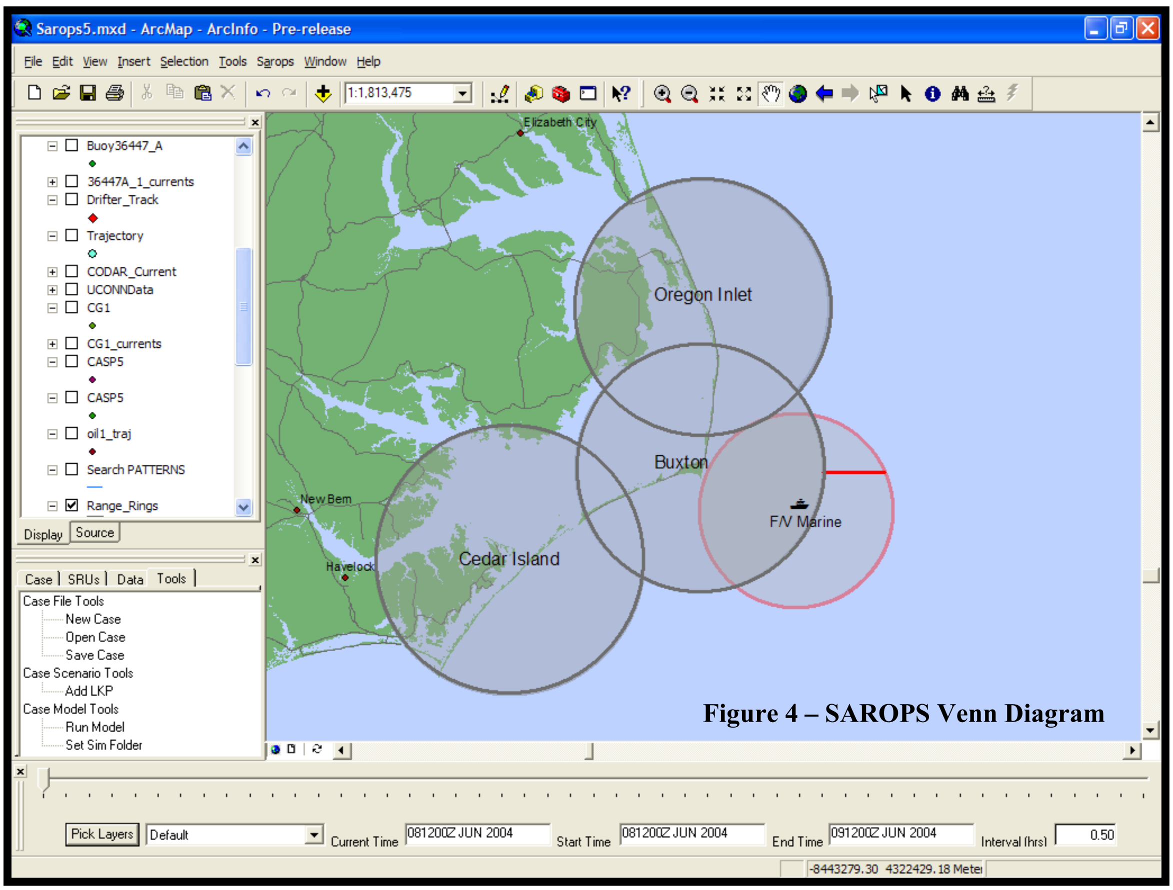

Figure 4 – SAROPS Venn Diagram

Emergency Position Indicating Radio Beacons (EPIRBs) are used as distress signaling devices by most ocean going vessels. The beacons are attached to brackets that allow the beacon to automatically release and activate when a vessel sinks. The beacon then sends a signal that is picked up by satellite and forwarded to the Coast Guard.

At 102330Z SEP 06 the SAROPS system flashed an alert and plotted the position showing the location of the AMERICANA 406 Mhz EPIRB. Contained in the EPIRB's SARSAT message was the registration information that identified the vessel as S/V AMERICANA owned by W.L. Herndon of Virginia. A phone call and database query confirmed that the vessel was a 42' deep keel cruising style sail boat en route from Panama to New York, with 5 persons aboard. LT Thompson considered this news a solid correlation with the earlier MAYDAY, excepting that the SARSAT position provided was almost 10 miles SW from where his earlier analysis predicted. LT Thompson knew that his evening was just getting started, as the poor weather would not allow an immediate "Hit it Hard and Hit it Fast" launch. Deployment of resources would need to wait until first light. In the mean time, he would monitor the situation (i.e., weather, communications, and available resources), issue an Urgent Marine Information Broadcast (UMIB), brief his Chain of Command (CoC) and plan the first light search. Unfortunately, the weather was likely to change little as the storm was predicted to stall off the coast. The EPIRB was also uncooperative as there was only one additional message that evening which did correspond to its earlier position and his earlier analysis once adjusted for set and drift.

The situation was not great but it was understood. Historically this has not always been the case, but with modern GIS tools and adequate data feeds the picture was clear. The storm was raging. The vessel in distress was the AMERICANA with crew of 5. The LKP was 35-05N 074-57W at 102350Z SEP 06. The UMIB was out. CDR Frost, his boss, was briefed. AIRSTA E-City had fixed and rotary wing aircraft ready for morning operations. Also available was a 123' Patrol Boat from Portsmouth and a 47' Motor Life Boat from Station Oregon Inlet. The time between the LKP and the Mean Search Time (MST) was roughly 17 hours. This isn't huge as far as drift intervals go, but with 60+ knot winds and heavy seas there would be quite a range in possible drifts. LT Thompson used SAROPS to review and visualize the situation and began formulating a plan to determine which resources would need to head out in the morning.

LT Thompson activated the SAROPS "Wizard" to enter LKP, incident time, vessel type, drift interval, Hurricane Hunter Observations and available resources. He chose to consider two possible situations; one which focused on the vessel and another based on a life raft. The fact that there had been SARSAT messages (although limited) and no further radio communications led him to think that the AMERICANA may have been lost. The SAROPS extension stored the case within an XML data structure and fed it to the drift simulator. The simulator ran two thousand replications, each of which represented how the vessel might drift given a particular set of environmental inputs and probabilistic variability. The simulator then returned a shape file to the GUI that represented a probability density distribution of the vessel and raft locations at the mean time of the next day's search (MST). The simulated plot looked reasonable but not necessarily intuitive to LT Thompson as the wind was clocking from NE to W and the Gulf Stream current from the SE. The result was an area approximately 50 miles long by 60 miles wide centered about 45 NM ESE of Cape Point. A defined probability map was half the battle, or at least LT Thompson's battle, now he needed to determine how best aircraft and cutters should search most effectively.

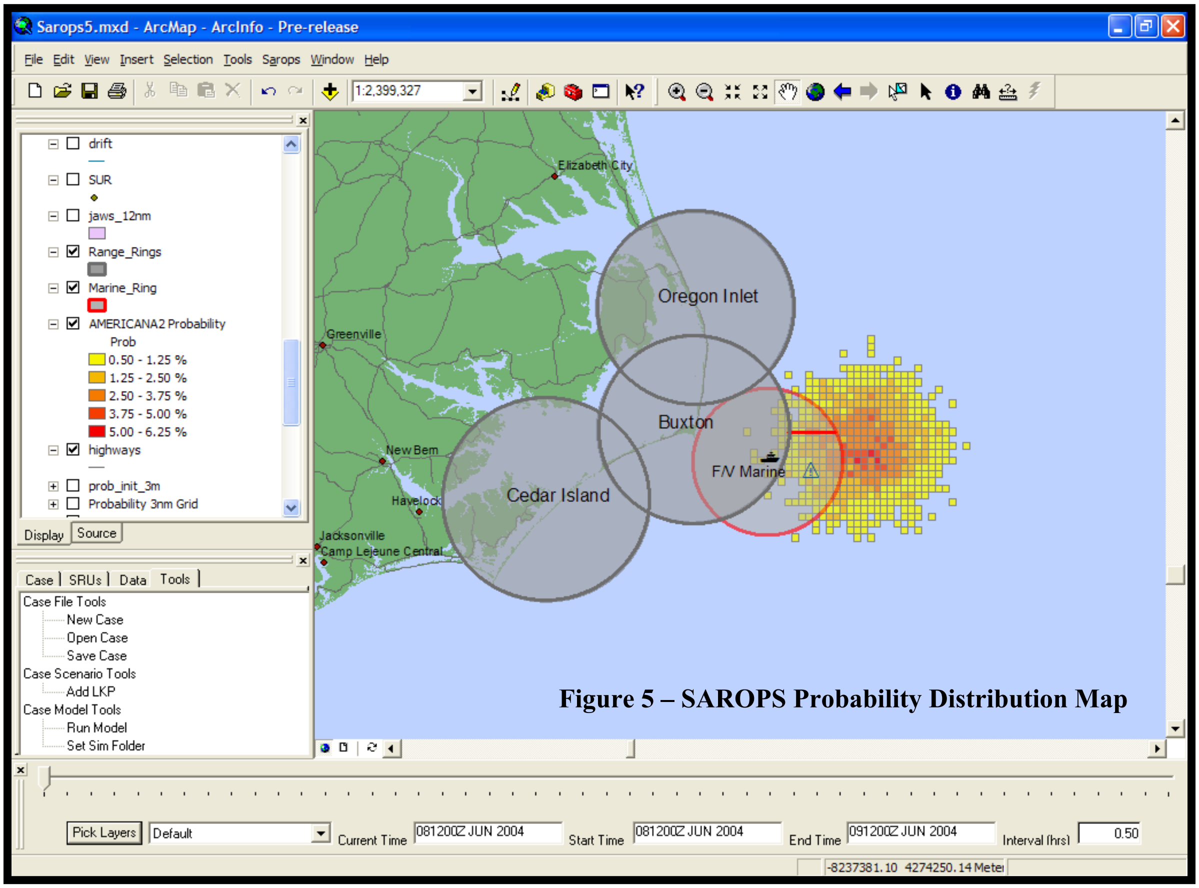

Figure 5 – SAROPS Probability Distribution Map

During the night the cutters got underway and the air crews prepared for flight. The hurricane tracked to the south and inland, which meant that clearing winds would come around from the W by morning. This would help to drop the sea state and allow better visibility.

Environmental factors in combination with the search object and search craft characteristics are fundamental in determining search pattern track spacing. There is an inherent trade off in search planning between how thoroughly an area is searched and the size of the area. On one hand, a search area with a high coverage factor yields a high Probability Of Detection (POD). The problem is that the size of the area that can be searched with a high coverage factor is smaller than the size of an area searched with a lower coverage factor. If the search object isn't within that area it will not be found, period. On the other hand, a lower coverage factor allows a greater area to be searched; the problem here is that the search object could be overlooked. Fortunately, the SAROPS simulator optimizes the coverage factor (i.e., the search patterns' track spacing) to maximize the Probability of Success (POS). POS is the product of POD and the probability the search object is in the area being searched (i.e., the Probability of Containment, POC).

LT Thompson next entered available resources with the Wizard and let the simulator compute the optimized search patterns. LT Thompson performed minor adjustments given his practical experience to create a Search Action Plan (SAP) that met his satisfaction.

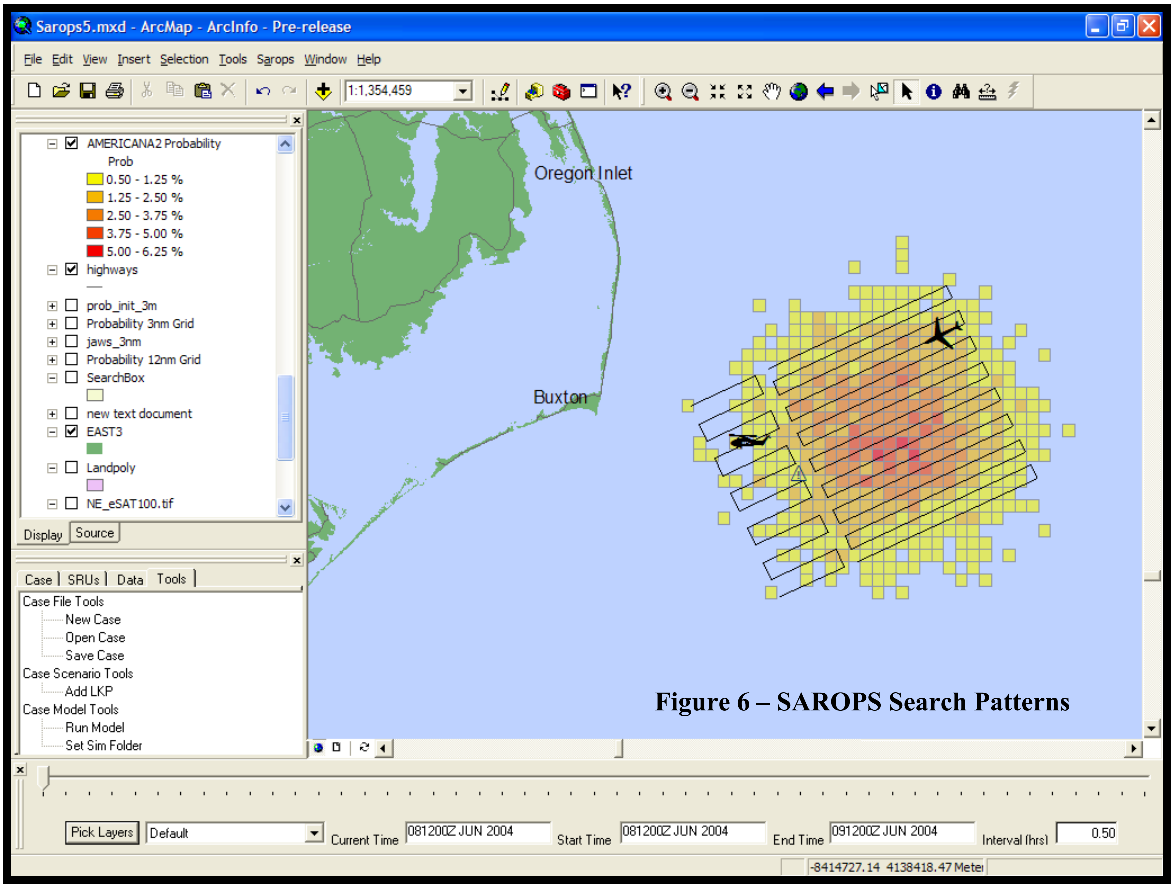

Figure 6 – SAROPS Search Patterns

The SAP, with pattern summary reports, were sent out and entered into the search craft's respective navigation systems. The Helo and C-130 both ran parallel searches and a 123' cutter moved on scene to lend assistance. On its third leg the Helo spotted the vessel with all aboard. There was no engine activity, but a storm jib was up and sea anchor deployed. *These (unexpected) factors combined with a persistent landward tack edged the AMERICANA to the eastern edge of the probability map*. The engine had been flooded and electrical system fouled early in the storm. The EPIRB was washed overboard during a roll and had self activated; the cause of its intermittent and short-lived signal was not known. The Helo crew determined the AMERCANA was no longer in immediate danger; therefore, no rescue swimmer was deployed and no persons evacuated. Instead, a pump was dropped; the Helo was relieved by the C-130 who circled overhead until the WPB-123 arrived 90 minutes later. With the hull pumped, Captain Herndon was able to raise partial sail and return to port under escort of the WPB-123 without further event.

Acknowledgements:

Readers may notice similarities between this story and the loss of the SS Central America in the same general area on September 11, 1857. The SS Central America had carried nearly 600 passengers and 20 tons of California gold. In the late 1980's the wreck was discovered in over 8,000 feet of water (using a predecessor to SAROPS to plan the high-tech sonar search). For those not familiar with this historical event and later salvage, the book, Ship of Gold in the Deep Blue Sea by Gary Kinder is highly recommended reading.

The SAROPS system is currently under development scheduled for deployment in 2006. Northrop Grumman, a key contributor to the USCG's C4I systems is the prime contractor and responsible for overall integration of SAROPS. Applied Science Associates (ASA Inc.) is responsible for the Environmental Data Server and GUI. Chris Galagan of ASA created the screen captures shown above with an early SAROPS prototype. Metron Inc. is developing the SAROPS simulator engine under the watchful eye of Dr. Larry Stone. Dr. Stone is the mathematician responsible for the probability maps that led to the location of the USS Central America in 1987 by the Columbus Discovery Group formed and led by Tommy Thompson.

End Notes:

The satellite image shown above is of hurricane Isabel, which ravaged Hatteras Village, NC and impacted most of the mid Atlantic Coast in September 2003. Given today's Coast Guard and modern technology many more, possibly even all of the 425 lives tragically lost in 1857, would have been saved. As it was, passing vessels were able to save 150+ lives, otherwise all would have perished and no one would have known of the SS Central America's loss until she became overdue in New York. The town of Herndon, Virginia is named in honor of Captain Herndon of the SS Central America, who went down with the ship after extraordinary efforts to save as many of the passengers and crew as possible. The fictitious, but not farfetched, example above reflects common aspects of the many SAR operations expertly conducted by the U.S. Coast Guard.

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Author Information:

Robert Netsch is a systems analyst / project manager at the US Coast Guard Command and Control Engineering Center in Portsmouth, VA. He has a BS in mathematics, a MS in software engineering and has been involved with the development and fielding of C2 systems for 15 years. For the past 5 years Robert has worked on the C2PC/SAR Tools effort in support of Maritime Search and Rescue planning. C2PC/SAR Tools will be replaced with a new system called SAROPS (Search and Rescue Optimal Planning System) in FY06.

US Coast Guard C2CEN
4000 Coast Guard Blvd
Portsmouth VA, 23703

v) 757-638-2762
f) 757-686-2113
rnetsch@c2cen.uscg.mil or rnetsch@earthlink.net