Revisiting the *SS Central America* Search

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Abstract – In 1857, while carrying passengers and gold from California to New York, the SS Central America sank in a hurricane, taking some three tons of gold bars and coins to the ocean bottom almost 8,000 ft below. Some 425 people, including the captain of the ship, lost their lives. In 1989, after three summers of effort at sea, the Columbus America Discovery Group recovered one ton of gold bars and coins from the wreck. This paper reviews the analysis that was performed to produce the probability distribution used to plan the successful search for the wreck and critiques that analysis based on information obtained in the years since the original 1992 article was written on this topic. This paper also provides an update on the legal battles and the disposition of the recovered gold.

Keywords: Bayesian, probability, subjective, estimation, search.

1 Introduction

In 1857 people travelling from California to New York had three choices. They could travel by land across the continent, enduring a long arduous journey and braving the dangers of Indians, weather, disease, and exhaustion. They could undertake a long sea journey around Cape Horn fighting their way through terrible storms at the southern-most tip of the South American continent. Or, they could travel by steamer from San Francisco to the west coast of Panama, cross the isthmus by train, and take a steamship to New York.

Between 1848 and the completion of the transcontinental railroad in 1869, the steamship route via the Isthmus of Panama was the main mode of transportation between California and New York. The U.S. mail steamship *SS Central America* was one of the ships operating on the Atlantic side of the Panama route. On the 20th of August 1857, the U.S. mail steamer *Sonora* left San Francisco carrying about 600 passengers and crew and three tons of gold bound for New York. After an uneventful trip to Panama and a train ride across the isthmus, the passengers embarked on the *Central America*, and set sail for Havana and New York.

The ship left Havana on the 8th of September in clear weather. On the 9th it ran into a storm which developed into a hurricane. The ship sprang a leak on Friday morning the 11th. After heroic efforts by the passengers and crew to save the ship Friday night, Captain Herndon realized at midday Saturday that ship was doomed and ordered the women and children to be taken off to a nearby ship, the brig *Marine*. At 8 pm that night, the passengers onboard the *Marine* saw distress rockets fired from the deck of *Central America* and watched as the lights of the ship disappeared beneath the ocean surface.

As the ship went down, many passengers and crew, including the ship's captain, William Lewis Herndon, a Commander in the U.S. Navy, were dragged down to their deaths. Some managed to grab hold of pieces of the wooden superstructure of the ship and stay afloat until dawn when they were rescued by the bark *Ellen*. Miraculously, there were also three men who drifted for eight days on a raft and in a life boat before being picked up near New York City.

In 1985 the Columbus America Discovery group tasked the author to produce probability maps (distributions) for the location of the wreck. In the sections below, we describe the methods used to produce the probability maps, the search plan based on it, and the results of the search. We then provide a retrospective analysis of the probability distribution and the methods used to derive it. Such critiques are important tools for improving the process of search planning. In addition we provide an update on the legal battles over the ownership of the gold and its final disposition based on information obtained after the publication of the original article [1] describing the search planning process.

The book, *Ship of Gold in the Deep Blue Sea* [2], provides a highly entertaining description of the search operation itself including a history of the gold rush and background on Tom Thompson and other members of the Columbus America Discovery Group.

2 Columbus America Discovery Group

The Columbus-America Discovery Group was formed in 1985 to conduct multi-disciplinary research, to develop sophisticated deep-ocean technology, and to locate, explore, and recover the remains of the *SS Central America.* Thomas G. Thompson, director and founder of the Central America Project, received a BS in mechanical engineering from the Ohio State University. He followed his strong interest in ocean engineering and exploration by serving as chief engineer aboard research vessels operating in the Caribbean and Pacific Oceans. He also designed, constructed, and maintained underwater search and recovery equipment. From 1980 to 1987 he worked as a research scientist with the Battelle Memorial Institute studying, among other things, the feasibility of mining polymetallic sulfides from the deep ocean.

In 1975, Thompson took up lost shipwrecks as a hobby and began to collect information on shipwrecks around the world. In the early 1980s, new technologies were developed for sonar search and for remotely operated recovery vehicles. Newly developed sonars could scan large swaths of the ocean bottom with high resolution. Advances in robotics, fiber optics, and computers made it possible to build remotely operated underwater vehicles capable of performing a full range of archaeological recovery tasks. This technology eliminated the need for manned submersibles, which are expensive and dangerous to operate in the deep ocean. These developments made it economically feasible for a small, independent entrepreneur to search for and recover objects on the deep-ocean floor

Bob Evans, one of the project directors, joined Tom Thompson in 1982 and began researching historic wrecks. The *Central America* emerged as a prime candidate for recovery. Several factors influenced this decision. The wreck of the *Central America* is located on the Blake Plateau, some 200 miles east of Charleston and 1.5 miles below the ocean surface, in an area with a flat bottom and little current. Because of the great depth, the ship was safe from damage by storms and hurricanes as well as from casual exploration by SCUBA divers or treasure hunters. The flat bottom and lack of current allowed for the efficient use of wide-scan sonar for the search. The ship was known to be carrying large quantities of gold, making its location and recovery economically attractive to investors. There was a great deal of historical information available about the wreck. Finally, the wreck was located off the coast of the United States so that legal problems could be handled through the U.S. courts and law.

2.1 Goals

The Central America Project had the following goals: locate the wreck of the *Central America* and recover gold and historical artifacts in a responsible manner; develop new technology for deep ocean exploration; add to the historical knowledge of the *Central America* and its times; and increase the scientific understanding of the deep ocean environment and its inhabitants.

2.2 Problems

The problems that the Central America Project faced were financial, technical, operational, and legal. The financial problem was to raise the money needed to fund the search and recovery effort. This was done by forming a limited partnership with investors providing about 10 million dollars in capital to fund the effort. The technical problems were numerous including (1) choosing a wide-swath high resolution sonar and developing an image processing system to go with it, (2) constructing a probability map for the location of the wreck, (3) developing a search plan to produce a high probability of success, and (4) designing and building a remotely controlled vehicle to search for and recover delicate artifacts in 10,000 feet of water. The operational problems included leasing a ship, hiring a crew, and training them for the search and recovery operation.

The legal problems included protecting the wreck from pirate salvors intent on taking advantage of the work done by the Columbus-America Discovery Group and fending off claims by insurance companies and others to ownership of the gold after it was recovered

This paper discusses only the development of the probability maps and search plans as well some of the legal problems encountered.

3 Search Problem

The first part of the search problem was to produce an estimate of the location of the target. Following the paradigm developed by Bernard Koopman [3] and his colleagues in the Navy's Operations Evaluation Group during World War II, we stated this estimate in terms of a two dimensional probability distribution on the location of the wreck.

To develop this distribution, we made use of the following information:

Historical:

- Herndon's last reported position as passed to the schooner *El Dorado*;
- Sighting of the *Central America* by the brig *Marine*;
- Recovery of survivors by the bark *Ellen*;
  An estimate of the wreck's location by Captain Badger, a passenger on the *Central America* who was rescued by the *Ellen*;
- Estimates of wind speed and direction recorded during the hurricane.

Statistical:

- Historical distribution of winds and currents in the area,

Analytical:

- Estimates of the uncertainty in celestial navigation;
- Estimates of the effect of wind on the drift of the *Central America*; and
- Estimates of the wind-driven current.

Subjective:

- Weights representing, the quality of the information used to estimate the wreck's location,

3.1 Methodology

The methodology for combining these diverse types of information had its start with work done by Richardson [4] during the 1964 search for an H-Bomb lost off the Mediterranean coast of Spain. In many search problems the information about the target's location comes from a variety of sources and is often inconsistent. The information does tend to cluster into self consistent sets, each of which tells a "story" about the location of the target. The clusters are called *scenarios*.

The methodology was further developed in [5] during the search for lost U.S. nuclear submarine *Scorpion* and was used by the U.S. Coast Guard in its original computer search and rescue planning program [6] as well as in the updated version called Search and Rescue Optimal Planning System (SAROPS) [7] fielded in 2007.

The information in each scenario is carefully quantified. Uncertainties are represented by (possibly subjective) probability distributions. A Monte Carlo simulation is used to produce the probability distribution corresponding to each scenario. Scenarios are assigned subjective probabilities based on the strength and quality of information comprising them. The Coast Guard recommends that a team of people be employed for this process. The team discusses the merits and shortcomings of each scenario. Then each team member assigns subjective probabilities to each scenario. The probabilities add to 1. These individual estimates are averaged to produce the subjective probabilities used to compute the probability map for the location of the search object. The final probability map is produced by computing the mixture of the scenario distributions weighted according to the averaged subjective probabilities. The Coast Guard methodology emphasizes that no scenarios should be dropped because they are unlikely. Instead, these scenarios should be included but given low probabilities.

Here are the basic steps of the approach:

(1) Gather all relevant information about the loss.
(2) Organize the information into self-consistent clusters, each of which becomes a scenario that can be used to provide an estimate of the location of the wreck.
(3) Quantify the uncertainties in the information in each scenario in terms of probability distributions.
(4) Using these probability distributions, run a Monte Carlo simulation to compute a probability map for the location of the wreck resulting from each scenario.
(5) Assign subjective probabilities or credences to each scenario and produce a composite probability map that is the weighted sum of the probability maps for each scenario.

3.2 Scenarios

Figure 1 shows a map of the general area of the *Central America* loss and indicates some of the important positions used in constructing the probability map. The information appeared to cluster into three self-consistent scenarios. The first scenario was based on the position given verbally by Herndon to C. Sherlock, the first mate of the schooner *El Dorado* at 6:00 pm on Saturday. The second was based on the reckoning by Captain Burt of the position of the *Marine* when it sighted the *Central America* about noon on Saturday. The third is based on the celestial fix taken by the *Ellen* at 8:00 am on Sunday as she was recovering survivors from the *Central America*. A glance at the positions in Figure 1 shows the amount of variation in this information. For example, the distance between the Herndon position and the *Ellen* position is about 60 miles. Captain Badger, a passenger on the *Central America*, who was rescued by the *Ellen*, provided an estimate of the location of the wreck which is shown in Figure 1.

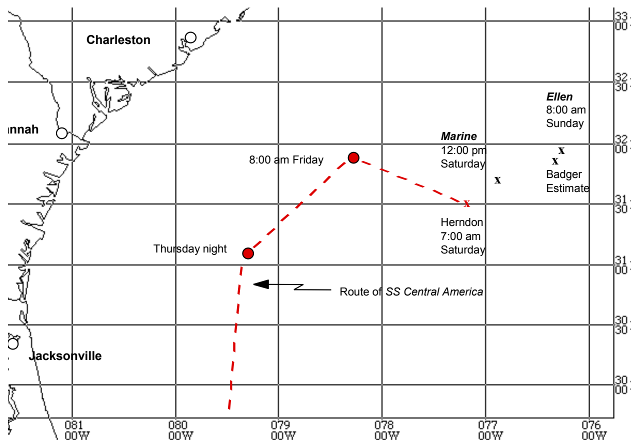

Figure 1: Route of *SS Central America*

3.2.1 *Central America* Scenario

The primary piece of information in the *Central America* scenario is the position of the *Central America* passed by Captain Herndon to the *El Dorado*. The position was passed in the midst of the storm just two hours before the ship sank. This raises the immediate question of when and how this position was taken. The only methods for estimating one's position at sea were to obtain a celestial fix or to dead reckon from the last fix. By studying the accounts of the disaster, Evans determined that there was a clearing in the storm on Saturday morning around 7:00 am at the time of a lunar meridian, the high point of the moon above the horizon for that day. Evans also determined that Herndon returned his navigational instruments to the cabin of Judge Monson, a passenger on the *Central America*, at 8:00 am on Saturday morning. On the basis of this evidence we surmised that Herndon had taken a celestial fix at 7:00 am on Saturday morning and that the position relayed to the EI Dorado, 31°25'N, 77°10'W, was this fix.

How accurate was this fix, and what does it tell us about the location of the *Central America* when it sank 13 hours later? To answer these questions, we examined the method by which the celestial fix was taken. We assumed that a sextant was used to determine the altitude h of the meridian of the moon measured in degrees from the horizon, and that a chronometer was used to estimate the Greenwich Mean Time at which the meridian occurred. From standard navigational tables one obtains the declination, d, of the moon at this time. The declination is the angular height of the moon's meridian measured from the equator. The latitude, L, of the observer is calculated by

$$L = d + 90 - h .$$

Using these same tables, one determines the Greenwich Hour Angle (GHA) of the moon at this time. The GHA is equal to the longitude of the observer. To determine the accuracy of the fix, Belkin [8] analyzed the errors in this navigational method. Characterizing the uncertainties in the estimation of latitude and longitude as bivariate normally distributed with mean $(0,0)$, he obtained the following estimates of the standard deviations, σ_{lat} and σ_{lon}, of these uncertainties:

$$\sigma_{lat} = 0.9 \text{ nm and } \sigma_{lat} = 3.9 \text{ nm} . \quad (1)$$

The uncertainty in longitude is more than four times larger than the uncertainty in latitude. The reason for this is that estimation of the longitude requires determination of the time of the meridian. The observed path of the moon had a rather broad apex making it difficult to determine the exact point at which the meridian occurred when using a sextant. This, rather than the error in the chronometer, proved to be the dominating factor in the longitude uncertainty. Determination of latitude requires only an accurate estimate of the altitude of the moon at the meridian and does not require knowledge of the time of the meridian. As a result there is less error in determining latitude.

Drift

Of course the *Central America* did not stay stationary during the time between the celestial fix at 7:00 am and when she sank at 8:00 pm that evening. During this time we know that her engines were disabled and that she had no sails hoisted. She was at the mercy of the winds and currents. In order to account for her movement during this time we estimated her drift. There are two components of drift:

- Drift due to the ocean current.
- Drift due to the effects of wind. on the ship (leeway).

Ocean Current. As one would expect, no one recorded the ocean current during the storm, so we had to estimate it indirectly. The ocean current is the sum of the geostrophic and the wind-driven current. One can think of the geostrophic current as the current that would be present if there were no wind. In order to estimate the geostrophic current, we used historical data obtained from the Naval Oceanographic Data Center (NODC). This data consisted of all ocean current readings in their data base that were taken in the month of September in the region from 30°N to 32°N and 76°W to 78°W.

The data in the NODC files spans the period from the early 1850's to 1974 and were obtained from many countries. This region was broken into sixteen 30-minute by 30-minute rectangles. Within each rectangle, we computed the mean and empirical covariance for the data. We then modelled the current in the rectangle as having a bivariate normal distribution with mean and covariance equal to the computed values.

Using the fact that three men drifted for eight days before being picked up near New York City, we determined that there was a generally north-easterly current at this time. With this in mind we computed the mean and covariance of the NODC data points lying in the northeast quadrant. This produced bivariate normal distributions with mean vectors having a speed of 1.0 to 1.5 nautical miles per hour (kts) in the northeast direction We took these bivariate normal distributions as our best estimate of the distribution of the geostrophic current during the loss of the *Central America*.

Wind acting on the ocean surface produces a surface current which contributes to a ship's drift. To estimate the winds, Evans returned to ships' logs and survivors' accounts to find estimates of wind speed and direction during the two days preceding the loss of the *Central America*. To account for the uncertainty in these estimates. we modelled the winds as having a bivariate normal distribution with mean equal to the value obtained by Evans and a covariance matrix that allows the wind to vary by as much as 45 degrees from its mean. Using a wind-driven current model supplied by the Naval Postgraduate School in Monterey California, we estimated the this current in terms of bivariate normal distributions with means between 0.2 and 0.4 knots and standard deviations equal to 0.1 knots along each axis.

The total current was taken as the sum of the geostrophic and wind-driven current.

Leeway

The direct action of wind on a ship also contributes to drift. This is called leeway. To estimate this component, we need to know the leeway factor f for the *Central America*. The leeway factor is the fraction of the wind velocity that is converted to drift as a result of the wind acting on the area of a ship that is above water. If the wind velocity is W, then the leeway (or drift) produced by the wind is fW. (Here, we assume that the ship drifts in the same direction as the wind is blowing. This is not always true.) Using blueprints obtained for the *Cenral America,* we estimated that $f = 3\%$.

Generating the Probability Map

The method we used to generate the probability map for the *Central America* is based on simulation. It begins by drawing 4,000 points from the bivariate normal distribution representing the position of the *Central*

America at 7:00 am on Saturday when Captain Herndon took his celestial fix. For each of these points the simulation makes an independent draw from the total ocean current distribution to obtain V, the total ocean current vector and an independent draw from the wind distribution to obtain the wind vector W. We specified a time increment $h = 6$ hrs for the simulation. The simulation computes the total displacement D for the increment by

$$D = (V + fW)h \tag{2}$$

This displacement is added to the initial position, and the process is repeated (with new draws for V and W at each time increment) until the time at which the *Central America* sank is reached. (We assumed that as the ship sank it went essentially straight to the bottom.) The final position of each point is recorded. We imposed a grid of two-mile cells and computed the number N of points falling into each cell. We assigned the probability $p = N/4000$ to the cell. Figure 2 shows the resulting probability map. The numbers in the cells shown in this and subsequent probability maps are probabilities multiplied by 1000.

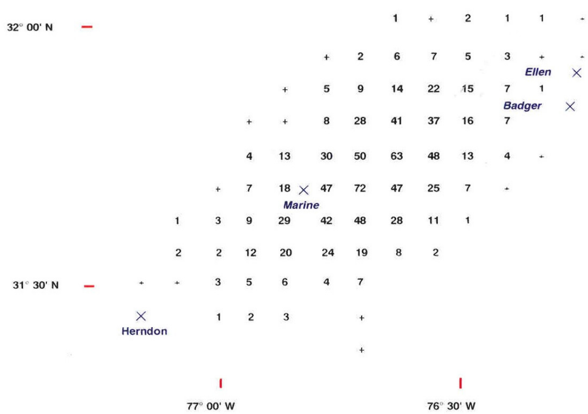

Figure 2: Map for *Central America* Scenario

3.2.2 *Ellen* Scenario

For the *Ellen* scenario, we used the position of the *Ellen* at 8:00 am on Sunday when she was recovering survivors from the *Central America*. The approach was to drift the survivors backward to the time of the sinking of the *Central America* to obtain an estimate of the position of the wreck. Note this is a *reverse drift* method of producing a scenario. This capability has been added to SAROPS and was used in the search for the wreck of Air France Flight 447 lost over the Atlantic in June 2009 [9].

At 8:00 am on Sunday, the captain of the *Ellen* took a celestial fix using a meridian of the moon. The recorded position was 31°55'N, 76°13'W. Using the same method as employed for Herndon's position, we estimated the uncertainty in this position as bivariate normal with mean $(0,0)$ and

$$\sigma_{lat} = 0.9 \text{ nm and } \sigma_{lon} = 5.4 \text{ nm} . \tag{3}$$

To obtain the probability map for this scenario, we made 4,000 draws from the bivariate normal distribution representing the *Ellen*'s position at 8:00 am on Sunday. A person in the water has no leeway, so his drift is determined solely by the ocean current. To produce this backward drift, we set the leeway factor to zero and multiplied the mean vectors for ocean current by minus one. Each point was drifted backward to 8:00 pm on Saturday when the *Central America* sank. The resulting probability map is shown in Figure 3.

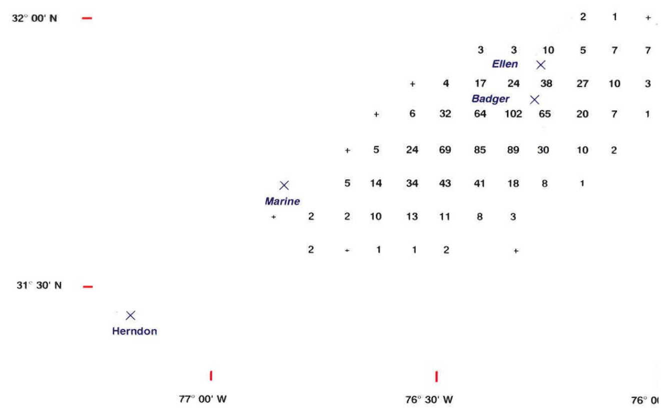

Figure 3: Map for *Ellen* Scenario

3.2.3 *Marine* Scenario

Captain Burt of the brig *Marine* sighted the *Central America* at 12:45 pm on Saturday. He recorded his position at this time as 31º40'N, 76º50'W. Our best estimate for the time of Burt's last celestial fix is 6:00 am on Friday. We assumed he had dead reckoned his position at the time of the sighting of the *Central America* since this last fix. Using a leeway estimate for the *Marine,* we estimated it had travelled 77 nm from the time of the fix and took the error due to dead reckoning to be at most 25% of this distance. The result is a mean $(0,0)$ circular normal error distribution with standard deviation 9 nm in each direction.

As well as accounting for the uncertainty in Burt's reckoned position, we also accounted for the distance of the *Marine* from the *Central America* at the time of the sighting. The *Marine* heaved to near the *Central America* at 1:30 pm, 45 minutes after the sighting. Assuming that the maximum speed of the *Marine* was eight knots, we calculated that the *Central America* could not have been farther than six miles from the *Marine* at the time of the sighting. We assumed that the minimum sighting distance was one mile. The *Central America* was sighted off the lee bow of the *Marine*. The *Marine* was reported to be running before the wind which was from the SW at this time. As a consequence we estimated the *Marine* to be heading NE and the lee direction off the bow to be ENE = 67.5°. We added an uncertainty of ±60° about this direction.

These estimates produced large uncertainties in the *Marine* scenario as is reflected the probability map shown in Figure 4.

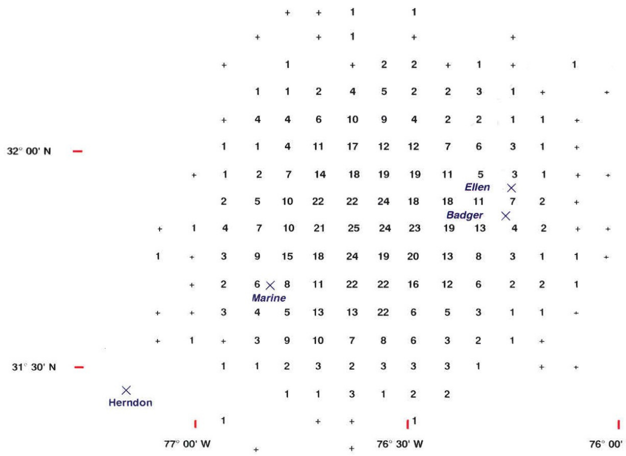

Figure 4: Map for *Marine* Scenario

3.2.4 Composite Probability Map

We combined the three separate probability maps by assigning subjective probabilities to the scenarios. Tom Thompson, Bob Evans, and Larry Stone each assigned probabilities to the scenarios after a joint discussion of the strengths and weaknesses of each scenario. The averaged probabilities are given below.

Central America 23%*, Ellen* 72%, and *Marine* 5%

The resulting probability map is shown in Figure 5.

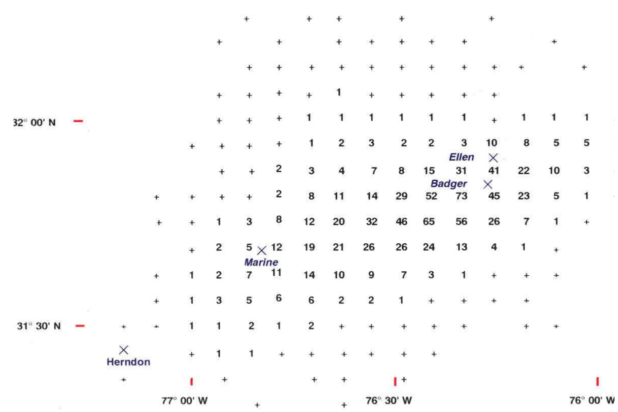

Figure 5: Composite Probability Map

The *Ellen* scenario was given the highest probability because the fix on which it was based was taken on Sunday morning after the storm had passed on a ship that was in no danger of sinking. In addition the position was recorded in the ship's log. By contrast, Herndon's position was taken Saturday morning while the ship was in distress and shouted verbally to the *El Dorado* at 6:00 pm on Saturday as the storm was rising once again. This is the reason for the substantially higher credence in the *Ellen* scenario. The Badger estimate also provided increased credibility to the *Ellen* scenario. The uncertainties in the *Marine* scenario were so large, that it did not provide much information and was therefore given a low probability. Nevertheless, following the Coast Guard methodology discussed above, we included it.

3.3 Search Plan

Based on the above map and estimates of the detection capability of the SeaMark IA side-scan sonar chosen for this operation, the estimate of probability of detecting the wreck as a function of search time shown in Figure 6 was developed. This estimate was crucial in convincing investors put up enough money to guarantee a high probability of success. They chose to fund the operation to obtain the 0.94 probability of success shown in Figure 6. This probability was computed from the search plan shown in Figure 7.

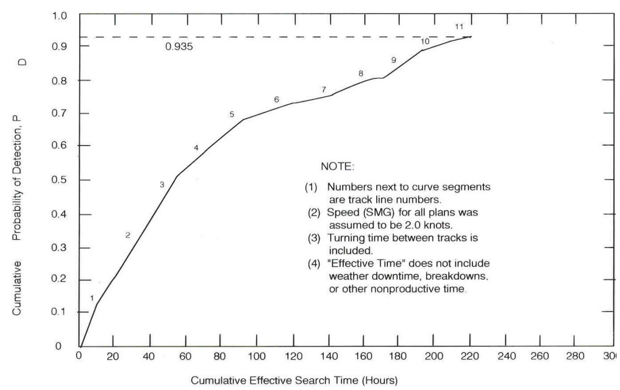

Figure 6: Probability of Detection vs. Search Time

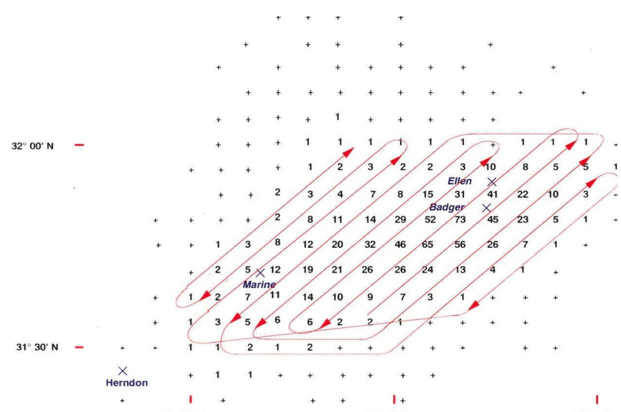

Figure 7: Search Plan

4 Search Operation

After preliminary testing of the equipment, the sonar search began in June, 1986. Early in the search, the sonar produced a very promising contact located southwest of the *Ellen* position in the cell having probability 0.056 of containing the target (see Figure 7). The size of the contact appeared about right, the sonar trace showed a mound that resembled a pile of coal, and the contact was in a high probability area. These facts produced a strong feeling that the sonar search phase should end right there, saving the more than one million dollars required to finish the planned search. In spite of this feeling, Thompson decided to press on to complete the sonar survey as planned. The survey took 40 days during the summer and covered approximately 1,400 square miles of ocean floor. It produced a number of interesting contacts including the early, very promising contact mentioned above.

The following summer, the Columbus America Discovery Group returned to search with their underwater vehicle, Nemo. Nemo is a remote-controlled device, equipped with stereo video, still cameras, and robotic arms. Using Nemo, they performed a visual survey of the contact in the high probability area southwest of the *Ellen* position and found the wreck of a wooden-hulled ship. In early July they recovered artifacts from the wreck that included lumps of coal, pieces of iron, ceramic dishes and pottery dating from the early 1850's as well as articles belonging to women and children. The group obtained an injunction to keep other salvors out of the first injunction area shown in Figure 8.

The remainder of the summer was spent exploring this wreck site. Over the winter of 1987-1988, the Columbus-America Discovery Group continued to review the computer records of other sonar contacts using image processing software. During this review, they discovered that one of the contacts that had been found near the end of the 1986 sonar survey had a look and texture similar to that produced by the coal at the wreck site investigated during the summer of 1987. The group decided that this second contact was worth further investigation. At the beginning of the summer 1988 cruise, the group began by testing its equipment in the area of this contact. On the first pass of the video cameras over the contact, two large iron-side wheels were spotted. Later; the bell from the *Central America* was recovered providing conclusive proof that this wreck was the *Central America.* The location of the *Central America* is inside the second injunction area shown in Figure 8.

At the end of this summer, a gold bar and several smaller pieces of gold were recovered providing much needed reassurance to the group and its investors. In the summer of 1989, the group recovered one ton of gold bars and coins from the wreck. In October 1989, this gold was handed over to the custody of the federal courts in Norfolk. In that same month 39 insurance companies filed claims to the gold along with a group of researchers from the Lamont-Doherty Geological Institute of Columbia University.

5 Critique

It is obvious that the wreck was found in a low probability area. Of course, one would like search objects to be found in a high probability area What does this say about the methods used to produce the probability maps and to plan the search?

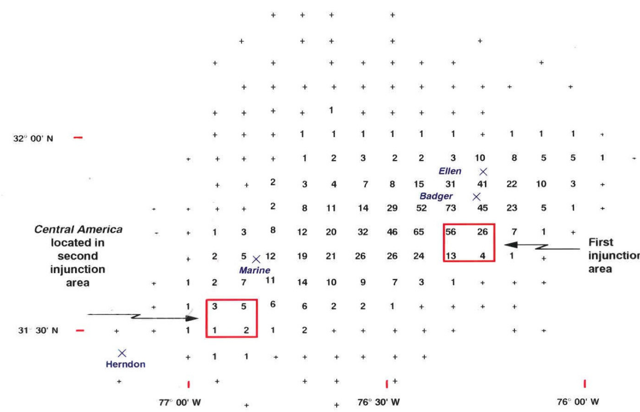

Figure 8: Location of the *Central America*

The first thing to say is the search was successful. Second, the careful analysis described above provided the basis for planning a thorough search with a high probability of success. This analysis convinced the investors to provide enough money to execute the search. Tom Thompson's insistence on following the plan even after the first very promising contact was found was crucial to the success of the effort. Other groups, including the one from the Lamont-Doherty Geological Institute had searched for the wreck of the *Central America* and failed. In each case, these groups failed to perform a careful analysis of the search problem and did not provide for enough effort to guarantee a high probability of success. They could have been lucky and found the wreck, but they were not.

The author feels that the results of the search show the value of careful search planning and the use of the multi-scenario process followed by the Coast Guard in their search and rescue planning. Persistence and careful planning enable success. There are very few extraordinary operations that proceed in the ideal fashion, and in 1986 this was an extraordinary and risky operation. Problems will occur, and plans will go wrong. This is not a surprise.

5.1 Methodology Lessons

This search highlights the importance of some basic Bayesian inference and data fusion methodologies:

(1) Express uncertainties in terms of probabilities using subjective probabilities when necessary.

(2) Use the weighted scenario method to incorporate inconsistent information. This appears to be a correct and effective way of fusing inconsistent information, at least for search problems

(3) Do not throw out low probability scenarios.

5.2 Improving the Process

While the search planning process worked, it could have been done better in a number of ways, some of which seem obvious in hindsight.

5.2.1 Scenario Weighting

It is clear that we did not give Herndon's information the weight that we should have. In hindsight it appears that Captain Herndon was a highly professional sailor to the very end. His fix was apparently more accurate than the one taken by the *Ellen* even though he was desperately fighting to save his ship.

5.2.2 Learn to live with dissonance

People strive to make information coherent even when it is not. In this case, we looked for and applied ways to move the probability distribution for the *Central America* scenario toward the *Ellen*. This is a bias. We should have treated the information in the *Central America* Scenario as independent of the that in the *Ellen*.

5.2.3 Additional Scenarios

We got into scenario lock. We should have considered additional scenarios. In particular we should have considered the possibility that the position relayed by Herndon to the *El Dorado* at 6:00 pm on Saturday was dead reckoned from his 7:00 am celestial fix. This scenario would have put substantial probability in the area where the wreck was found.

6 Disposition of the Gold

There were two court cases to determine the ownership of the gold. In the first case, the judge awarded Columbus America Discovery Group sole ownership, ruling that the insurance companies had abandoned the gold. This was overturned on appeal with the court saying the insurance companies had not abandoned the gold and that ownership must be decided according to the rules of salvage. In the second court case, the group was given a 92% salvage award and custody of the historical artifacts recovered from the ocean bottom.

In the years following 1989, the group borrowed large sums of money from Christie's using the gold as collateral and a promise that Christie's could auction the recovered gold. They used this money for operations that included historical work on the artifacts and marine biological research. As the years passed, with no sign that Thompson was prepared to offer the gold for auction, Christie's called in the loan asking for repayment or possession of the gold. The group was rescued by a rich sports agent who made a deal (details not known) and paid off the loan. The group began selling the gold coins and bars at coin shows in the 2000. Twenty dollar gold coins from 1857 are available from coin dealers in mint condition along with gold bars that were produced in San Francisco. Figure 9 shows some examples.

To date the investors have received no return on their investment despite the success of the group in recovering the gold. Investors are suing the group to recover their losses. Tom Thompson has become unavailable.

Figure 9: Gold Coins and Bars from *Central America*

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