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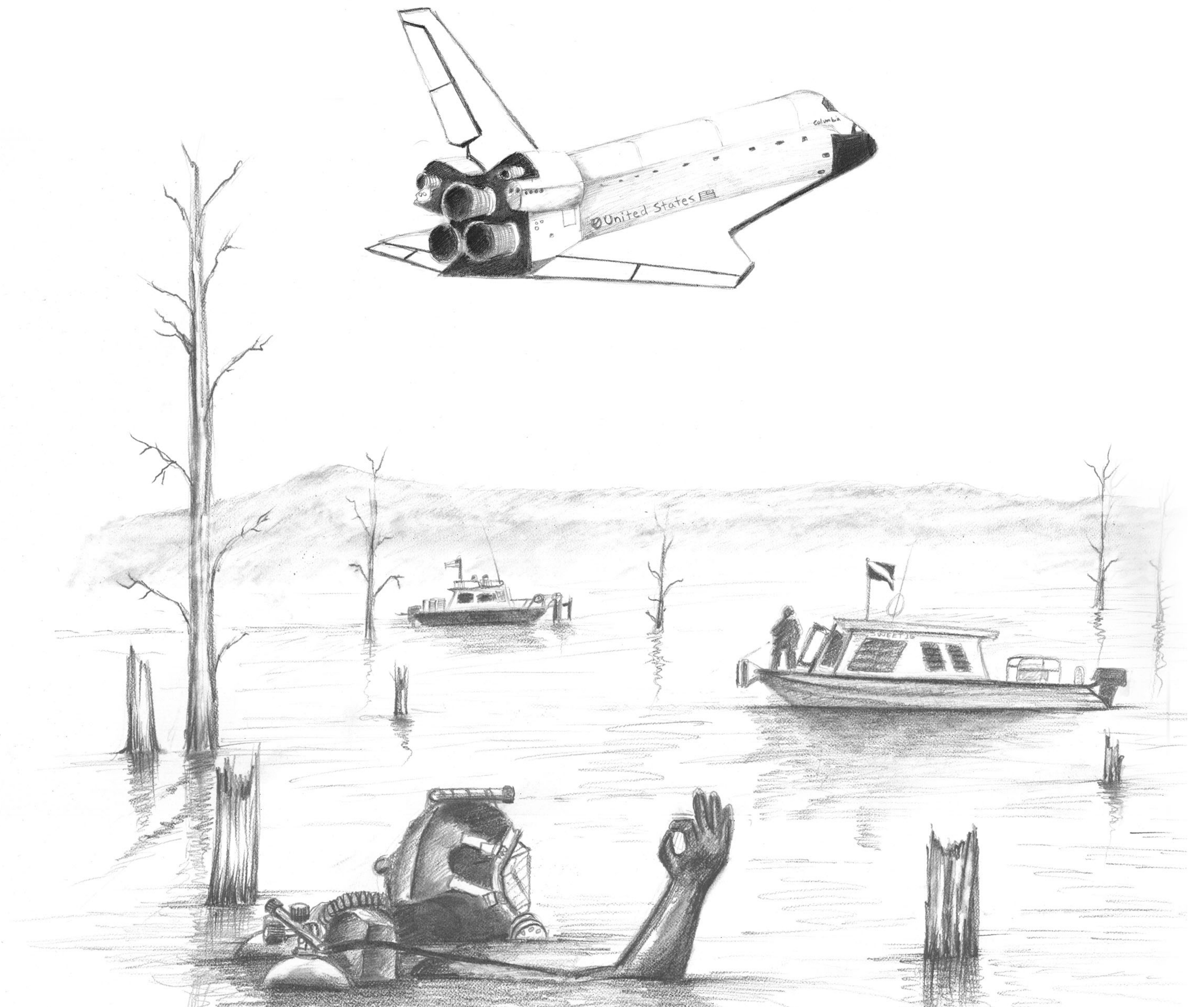
0910-LP-102-2949

U.S. NAVY SALVAGE REPORT
SPACE SHUTTLE COLUMBIA



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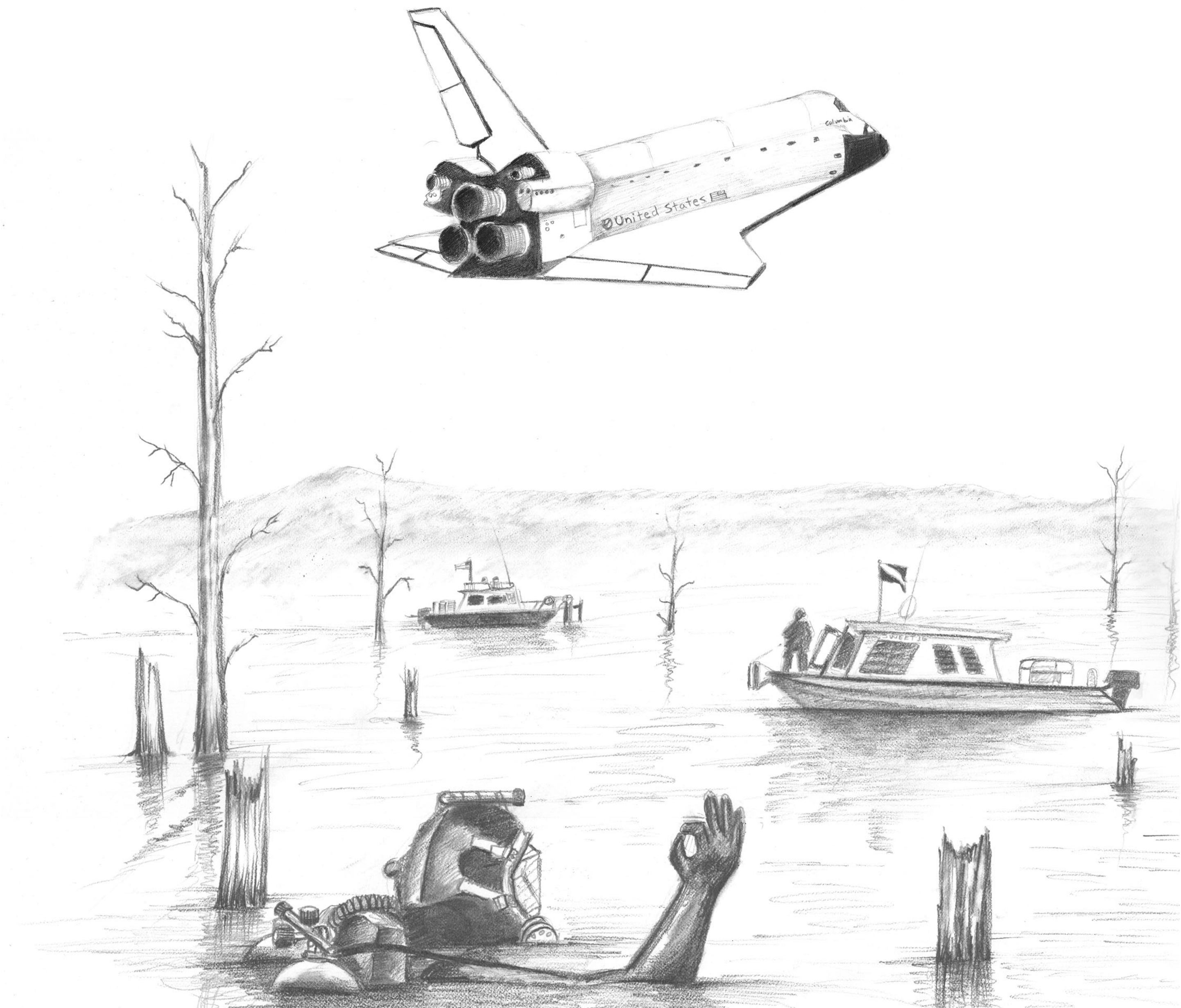

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Foreword

February 1, 2003 will be recognized in the annals of American history as a day of national tragedy and sorrow due to the in-flight disintegration of the Space Shuttle Columbia. This report chronicles the extraordinary efforts of hundreds of individuals comprising dozens of teams from federal, state and local agencies, industry, and private volunteer efforts which successfully undertook the daunting task of underwater search and recovery of Columbia debris from the reservoirs, lakes, and ponds of East Texas and Western Louisiana.

This is not the first time the Office of the Supervisor of Salvage (SUPSALV) has been called upon to lead national-level underwater search and recovery efforts, but it is unique for its unprecedented environment – an underwater forest. Over twenty square nautical miles of the dammed and flooded Sabine River and Sabine National Forest (renamed Toledo Bend Reservoir) were included in the principal debris zone of the Columbia disintegration. The acoustic and physical challenges presented by the tens of thousands of trees in the relatively shallow waters of Toledo Bend stretched existing technology and technique to the limit. This report carefully documents the operational and logistics challenges encountered, solutions reached, and lessons learned for future salvors confronted with similarly challenging environments.

What this report **cannot** do is properly recognize the enormity of the human spirit, enthusiasm, and sacrifice of the individuals that constituted this great underwater search and recovery Team. Their undauntable endurance and unflinching commitment to the successful completion of this search was an inspiration to all involved. This Team's legacy is nothing less than the future continuation of our Nation's space program.

J. R. Wilkins III
Captain, USN
Director of Ocean Engineering
USN Supervisor of Salvage and Diving

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Section 1

1 Introduction and Background

On February 1, 2003 NASA Space Shuttle Columbia (STS-107) suffered a catastrophic failure upon reentry into the Earth's atmosphere. The shuttle broke up over north central Texas scattering debris across several hundred miles. NASA, FEMA, EPA, and various Texas agencies quickly mobilized to collect this debris in an attempt to determine the cause of the accident. As two large bodies of water were along the debris axis, the Navy was asked to support the search effort. This report documents the water search that was conducted over a 60-day period.

1.1 Crash Details

The Space Shuttle Columbia was lost Saturday, February 1, 2003 at 08:59 EST, disintegrating 207,135 feet above Texas. Columbia was traveling at approximately Mach 18 en route to its scheduled landing at the Cape Kennedy Space Center in Florida following a successful mission. Columbia's seven-member crew: Commander Rick Husband (COL USAF), Pilot William McCool (CDR USN), Mission Specialists Mike Anderson (LCOL USAF), Kalpana Chawla (PhD), David Brown (CAPT USN), Laurel Clark (CDR USN), and the first Israeli Astronaut Payload Specialist Ila Ramon (COL IAF) perished in the disaster.

Within hours after the crash, accounts of debris falling to the Texas and Louisiana countryside were being received. The National Aeronautics and Space Administration (NASA), in coordination with Federal Emergency Management Agency (FEMA) and the Environmental Protection Agency (EPA), initiated a multi-agency state and federal effort to retrieve the debris in order to determine the cause of the accident.

NASA directed the search process with FEMA providing logistics and manpower to support the recovery effort. EPA was given primary responsibility as much of the debris was classified as hazardous. By February 2, analysis of the recovered debris and reports from eyewitnesses directed search and recovery efforts to areas including Lake Nacogdoches and Toledo Bend Reservoir in Eastern Texas. NASA began analyzing the final minutes of the flight in an attempt to determine the cause of the accident. It became clear that the source of Columbia's destruction was located in the vicinity of the leading edge of the left wing, and material from the left side of the spacecraft was listed as high-priority by accident investigators. They also indicated that any of the data recorders, cameras, and control systems would prove very valuable in assisting the determination effort.

All items that were classified as critical to the investigation were immediately cataloged and transported to the Lyndon B. Johnson Space Center in Houston, Texas. General shuttle wreckage collected during search operations was photographed, tagged, and its location recorded using the Global Positioning System (GPS). Once all information regarding target condition and location was recorded, the item was shipped to Barksdale Air Force Base in Louisiana. Over the following weeks, NASA continued to plot the location of recovered space shuttle debris. A number of charts were created based on this data, including one that reflected the location of all recovered debris and a second chart that reflected the location of "significant" recovered debris. In this case, the term "significant" was used to define recovered material that could prove helpful in investigating the cause of the accident. The plot of all recovered shuttle debris is provided as Figure 1-1. A plot of the significant debris field as of March 26 is provided as Figure 1-2.

1.2 Purpose of Report

This report is prepared to document the Navy's search for Space Shuttle Columbia debris in the lakes of East Texas as managed by the U.S. Navy's Director of Ocean Engineering, Supervisor of Salvage and Diving (SUPSALV). Hundreds of people from more than 38 organizations and nearly a dozen highly-specialized search assets were employed in this effort. Additionally, the search solutions and techniques crafted by SUPSALV's assembled team of specialists are documented for use, should similar environmental conditions be encountered in future salvage operations. This report identifies the challenges, techniques, and science involved in developing the most effective search solutions.

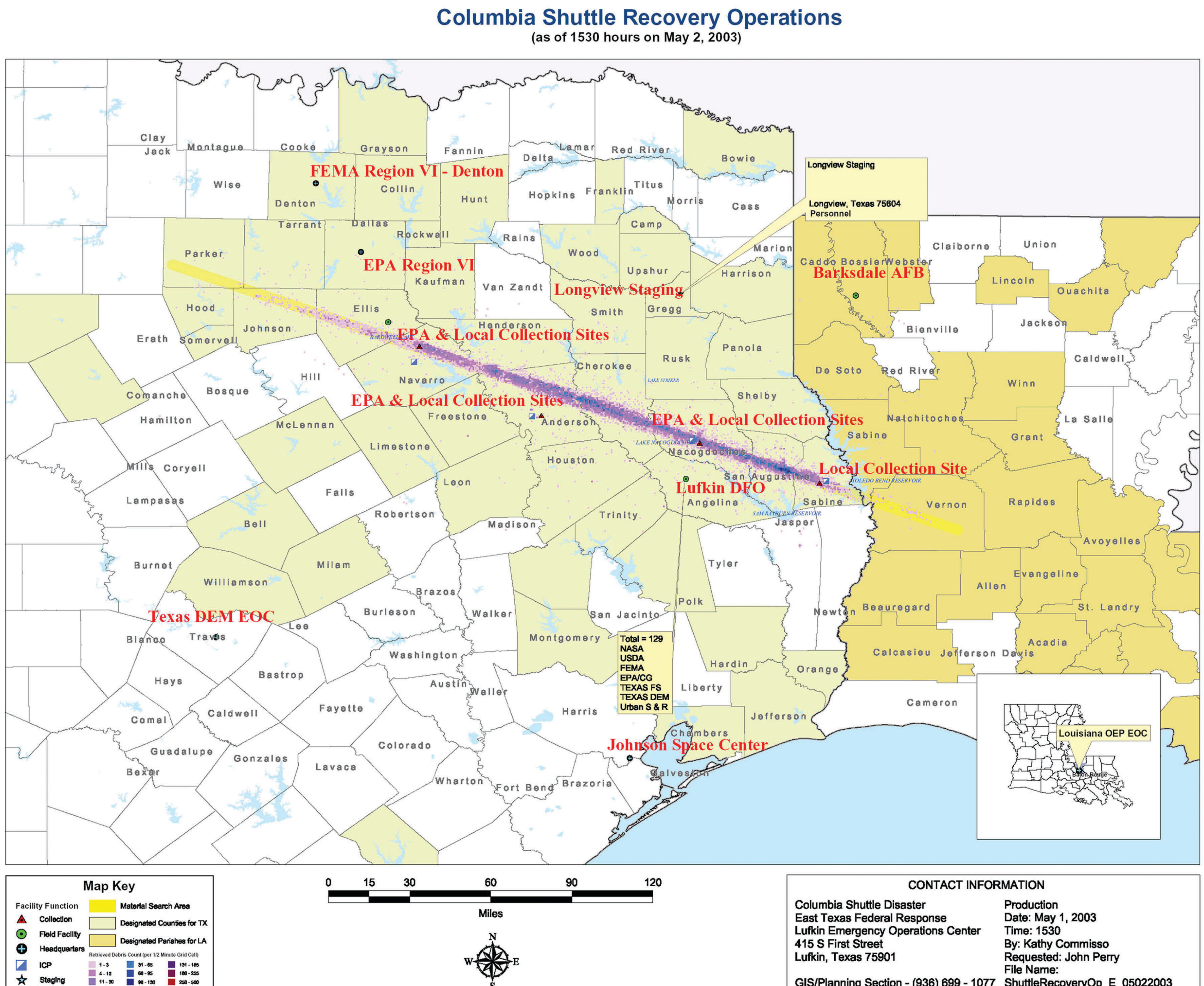


Figure 1-1. Plot of All Recovered Space Shuttle Debris

Left Wing Items Recovered
as of March 26, 2003

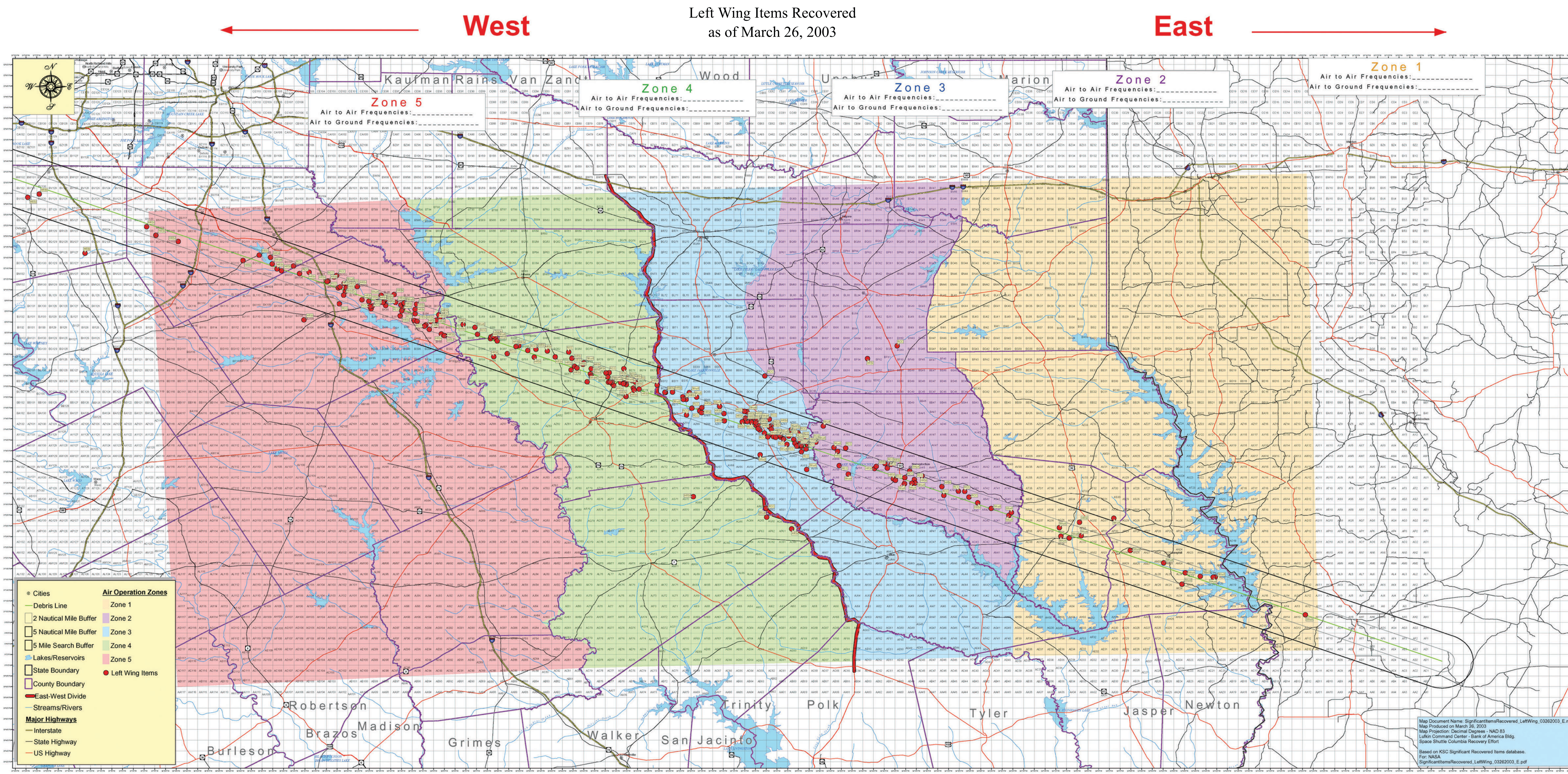


Figure 1-2. Plot of Significant Debris

1.3 SUPSALV Tasking and Scope of Mission

On February 1, the day of the shuttle accident, SUPSALV contacted the Operations Center at the Pentagon and indicated that SUPSALV was ready and able to assist the NASA effort if the search for shuttle debris included any bodies of water. At that time there was no request for assistance and therefore no official tasking was issued. NASA was relying on other federal and local resources for the water search.

On February 2, 2003, a NASA team was assigned to manage the search for shuttle debris in Toledo Bend Reservoir. The astronauts assigned to this task were Steve Bowen and Jim Reilly. Jim Reilly visited the reservoir on February 3 with EPA representative, Scott Harris. Assisted by the U.S. Coast Guard and the FEMA staff, they searched some of the shoreline in an attempt to locate and recover debris, but no debris was found. It became clear that an organized and extensive water-based search operation was needed.

During the first week, as the complexity and scope of the water search operations grew, NASA recognized that expert assistance was needed in organizing and managing the water search. The number of contributors, the expertise required to effectively manage them, and the difficulties being encountered on the lake presented more than enough evidence that an experienced and dedicated management team was needed for the task. By the end of the week, the NASA liaison team was actively searching for an organization that could assume responsibility for the operation.

On February 8, SUPSALV contacted the Director of Military Support (DOMS) representative at the Disaster Field Office (DFO) in Lufkin, Texas. During a teleconference call with FEMA, NASA, and EPA officials, SUPSALV indicated that the Navy was ready to provide a formal assessment of the feasibility of searching the lakes that were suspected of holding shuttle debris. NASA and FEMA accepted SUPSALV's offer and on February 9, a SUPSALV advance team consisting of CAPT Jim Wilkins (SUPSALV), CAPT Chris Murray (SUPDIVE), Mr. Tom Salmon (Salvage Division Head), and Mr. Ridge Albaugh (Phoenix International Project Manager) visited the area and met with Mr. Scott Harris (EPA) and NASA Astronaut Steve Bowen. They toured the area and observed existing operations.

On February 10, SUPSALV briefed the FEMA Federal Coordinating Officer (FCO), Scott Wells and NASA on the capabilities that the Navy and SUPSALV could bring to the recovery effort. They noted that non-standard GPS systems were being employed and that no formalized, coordinated plan for generating search coordinates or deploying assets was in use. Command and control and search expertise along with a number of dedicated, experienced dive teams were the primary assets the Navy offered. On February 10, FEMA officially requested that the Department of Defense (DOD) authorize the U.S. Navy to assist in the recovery effort via a Request for Federal Assistance (RFA). A copy of the original RFA along with Amendment 1, issued March 10, which extended the operation through April 30, and Amendment 2, issued March 17, which increased funding for the task are included in Appendix C.

On February 13, the Chief of Naval Operations (CNO) responding to FEMA's RFA, tasked SUPSALV to provide command and control of the underwater search and recovery effort, as well as provision of additional U.S. Navy assets and personnel to augment existing agencies' support. On February 14, Commander Atlantic Fleet (COMLANTFLT) tasked Mobile Diving and Salvage Unit Two (MDSU TWO) to respond with dive teams. Copies of the CNO and COMLANTFLT tasking orders are provided in Appendix C.

1.4 Overview of Operation

Initial review of the shuttle debris field indicated that a water search might be required in Lake Nacogdoches, Bardswell Lake, Lake Waxahachie, and Toledo Bend Reservoir. Analysis of collected debris gathered around Lakes Bardswell and Waxahachie ultimately ruled out a need for a water search in these two lakes as the debris found in surrounding shorelines was exclusively low density heat tiles that floated and would not have sunk to the bottom. Details on the remaining lakes are as follows:

- **Lake Nacogdoches** – Located on Loco Bayou, 10 miles west of Nacogdoches, Texas off FM 225. The lake is approximately 2,200 acres with a maximum depth of 40 feet. Lake Nacogdoches was dammed in 1976. The line of significant debris crossed the lower center of the lake and SUPSALV conducted their search on 3.17 square nautical miles of lake.
- **Toledo Bend Reservoir** - Located on the border of Louisiana and Texas, extending about 65 miles north of the dam site to Logansport, LA. The reservoir has approximately 1,200 miles of shoreline and is the largest man-made body of

water in the south and the fifth largest in surface area in the United States. Water surface normally covers 185,000 acres. Construction on the Toledo Bend dam began in April 1964 and was completed in October 1966. Center depths average between 40 and 80 feet with depths near the center of the river channel at 110 feet. The debris path search area covers approximately 17 square nautical miles of this body of water.

- **Local Ponds** - Based on eyewitness reports, several of the hundreds of small ponds covering south central and Southeast Texas were investigated.

The Navy-led water search concentrated all efforts on Toledo Bend Reservoir and Lake Nacogdoches using a combination of contracted search assets and dive teams from Navy, federal, state, and local activities.

Phoenix International, SUPSALV's search and recovery contractor, in concert with FEMA and NASA, developed the search plan, coordinated day-to-day search operations from the Fin and Feather Resort operations center and managed the database of targets and results. The search effort involved using various side scan sonar and multibeam bathymetry equipment on leased commercial workboats. Analysis was performed on the collected search data in an attempt to identify shuttle debris among the clutter on the lake bottom. Additional assets on the scene included a number of specialized marine search and hydrographic contractors and two Navy owned and operated autonomous underwater vehicles.

The diving effort was managed by SUPSALV with the assistance of MDSU TWO based in Norfolk, VA. In addition to the three to four dive teams the MDSU provided, teams from the EPA, Houston Police Department, Galveston Police Department, Galveston Sheriff's Department and, Texas Department of Public Safety performed diving services for the operation. A dive team from the New York office of the FBI also participated for a short period prior to the arrive of the U.S. Navy.

SUPSALV representative, CAPT Chris Murray took over initial dive operations command and control on February 12 working with NASA, FEMA, and EPA at Toledo Bend Reservoir. Organization and assessment of the assets on hand was the first order of business while awaiting formalized tasking and the arrival of additional Navy search and diving assets.

Navy operations commenced on February 15 on Lake Nacogdoches and Toledo Bend Reservoir using multiple search assets and diving teams. Lake Nacogdoches search was completed on March 10 and diving operations began that same week. The search continued on Toledo Bend Reservoir through April 11 with divers clearing all targets by April 12. The Navy demobilized on April 13 after identifying and diving on over 3,000 targets, two of which were classified as shuttle debris.

A graphical depiction of the operation is contained in Figure 1-2. This graphic combines the major milestones with the pace of diving and search operations to provide an overall summary of the operation. A detailed time line of the operation, containing all significant milestones and events is included in Appendix B.

1.5 Operational Considerations

The two main factors that significantly affected in the Navy's search and salvage operation were the small average size of the shuttle pieces that fell through the atmosphere and the very cluttered nature of the reservoir's bottom. Toledo Bend Reservoir can best be described as an underwater forest with the trees broaching the surface of the water. This environment presented challenges in running boats on the lake surface and made it very difficult to tow search sonars through the water column. Other operational factors that challenged the search teams are included below. Details of the challenges are discussed in Chapter 4.

- Long supply and logistics pipeline into rural East Texas
- Interagency coordination necessary to effectively operate as a team
- Winter weather conditions including strong winds on the lakes that interrupted the search process.

SPACE SHUTTLE COLUMBIA SALVAGE OPERATIONS TIME LINE OF EVENTS

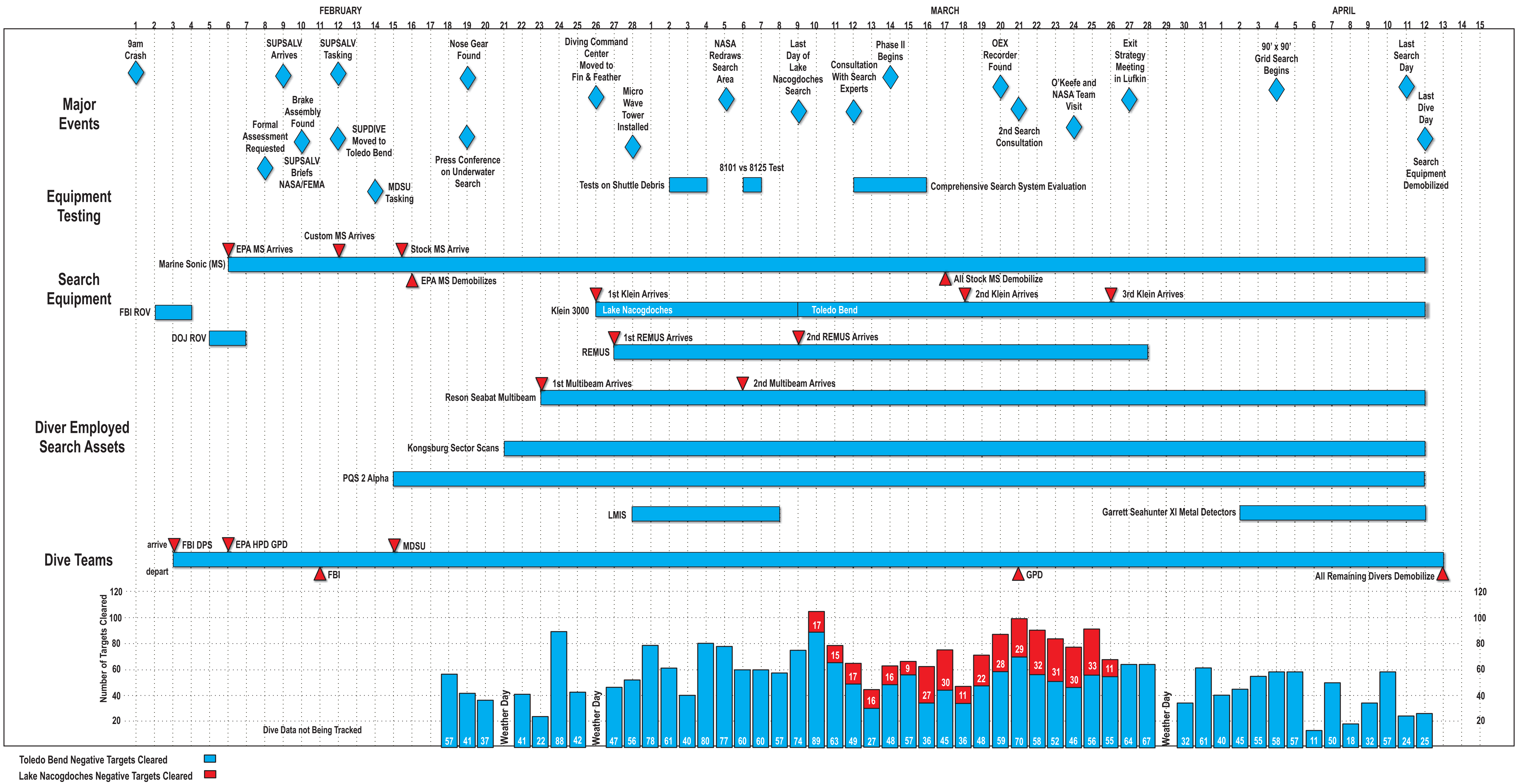


Figure 1-3. Time Line of Events.

Section 2

Command
and
Organization

Section 2
Command and Organization

2.1 Organizations Involved

After the Shuttle Columbia was lost on February 1, 2003, President George W. Bush issued emergency declarations for Texas (FEMA-3171-EM) and Louisiana (FEMA-3172-EM). FEMA became the lead agency for response and recovery operations. A major disaster declaration by the President is a prerequisite for federal response and recovery. FEMA coordinated federal agency response including utilization of the Department of Defense (DoD) assets. FEMA assigned a Federal Coordinating Officer (FCO) to the project who arranged funding and logistics for the operation. As DoD assets were tasked to respond, a Director of Military Support (DOMS) was also assigned. The DOMS staff in Lufkin served as liaison between SUPSALV and FEMA for the coordination of search and recovery services.

Response teams from various federal and state agencies deployed from their respective headquarters and regional offices. Disaster Field Offices (DFO) were established in Lufkin and Ft. Worth, Texas and Barksdale AFB, Louisiana. More than 60 federal, state, local, and volunteer agencies, and other private groups responded with personnel, supplies, and equipment. These included NASA, FEMA, EPA, U.S. and Texas Forest Services, DoD, U.S. Navy, U.S. Coast Guard, and the National Transportation Safety Board (NTSB).

The EPA was a major contributor to the effort. EPA teams were quickly dispatched to assist local emergency response teams since much of the shuttle material was potentially hazardous. EPA's primary mission was to ensure public safety, protect the environment, respond to located hazardous material, and collect shuttle debris. EPA provided major emergency response to both the land and the water search, providing teams of divers and contracting water search assets in the first week after the incident.

The U.S. Forest Service took the lead in managing the land search. Thousands of park and forest service personnel from all over the nation were provided to support the operation. The Forest Service also assisted the water search by providing geographic information systems (GIS) technicians who worked with the Phoenix team to plot search sectors and targets in the lakes.

2.2 Ground, Air, and Water Search

The debris field spread across more than 240 nautical miles of the Texas and Louisiana countryside. Initial unorganized recovery efforts resulted in inefficient accounting of the areas that had been searched. To ensure accountability for the search process, FEMA placed the responsibility for planning and conducting each phase of the search into the hands of three individual activities.

1. Ground Search – U.S. Forest Service.
2. Air Search – Texas Forest Service.
3. Water Search – U.S. Navy.

NASA continued to provide guidance and priority direction to each of the search teams based on analysis of the recovered debris. By the middle of February, NASA was distinguishing between general debris and "significant" debris that was critical in supporting the investigation into the cause of the accident. NASA redrew the center line of the debris field on February 20, 2003 based on the location of the significant debris recovered. This new line provided the datum from which the water search teams drew their search grids. A plot showing the location of the significant debris recovered as of March 26 is provided in Chapter 1 as Figure 1-2.

2.2.1 Ground Search

NASA, FEMA, and EPA organized a ground search beginning on the day of the disaster. Volunteers, local police, fire service, park service, and other agencies provided manpower for the initial search teams. As material was encountered, they informed the EPA whose hazardous material collection teams recovered the debris and moved it to a local staging area. The search area was refined as additional debris was recovered and coordinates of eyewitness sightings were plotted. As the requirement to conduct structured ground search across a large grid was established, FEMA tasked the U.S. Forest Service with managing the land-based search. The U.S. Forest Service brought manpower, infrastructure, and physical assets to the effort. Four Incident Command Posts (ICP) and debris staging areas were established along the path of the debris: Hemphill, Palestine, Nacogdoches, and Corsicana. Approximately 45 crews, consisting of 20 persons each, were housed, fed, and managed from each of these command posts.

By February 22 a plan was developed to walk the 240-mile path of shuttle debris. The search was carried out by U.S. Forest Service crews walking shoulder-to-shoulder across a 4-mile wide swath. The overall ground search involved a total of more than 16,000 personnel and covered over 680,000 acres. General shuttle wreckage collected during search operations was photographed, tagged, and its location marked via Global Positioning System (GPS) before shipment to the staging areas. Potentially hazardous debris was recovered by EPA crews. Once all information regarding target condition and location was recorded, the item was staged at the local ICP and ultimately shipped to Barksdale Air Force Base for transfer to NASA. As the spring progressed, the amount of high interest (“significant”) debris recovered on the northern edge of the four-mile wide swath led NASA to ask the ground search crews to expand their search to the north of the original line and to the west of the Corsicana grid sectors.

2.2.2 Air Search

Beyond the four-mile wide shoulder-to-shoulder ground search, NASA determined that some debris landed outside the primary debris path and that the ground beyond the four-mile swath would need to be searched. An air search was conducted utilizing 36 helicopters, 10 fixed wing aircraft, a RC-12 with multi-spectral capability, a DC-3 aircraft equipped with the COMPASS reconnaissance package provided by the Defense Intelligence Agency (DIA), several Civil Air Patrol aircraft, an ER-2 (NASA version of U-2 reconnaissance plane), and several motorized paragliders. The helicopters were flown at tree top level for an additional four miles on either side of the debris path in an effort to find shuttle wreckage. With spring progressing, the growth of foliage began to inhibit the ability of the air crews to see debris on the forest floor. For this reason, air search operations were paced so that they could be completed by the end of April.

On a good weather day, each helicopter could cover up to 900 acres, but it was difficult to see through thick tree canopies or fly too close to livestock. Areas that could not be seen from the air were assigned to the ground search teams. An air search crew consisted of a pilot, an aircraft manager who managed communications and positioning, and one or two spotters who searched the ground using gyro stabilized binoculars. By the end of air search operations, the crews had searched over 1,600,000 acres. Sadly, an air accident occurred on March 27, killing two crew members of one of the helicopters.

2.2.3 Water Search

NASA, EPA, and FEMA mobilized on the day of the accident and by February 2 had divers and searchers on the water. Water search and diving operations continued through April 12 when demobilization commenced. SUPDIVE took charge of all existing assets on February 13 and MDSU TWO arrived on February 15th with the first augment of divers.

NASA and EPA began the water search using teams who were on scene in East Texas. Eyewitness reports were coming in reporting debris in yards, fields, and other more traveled locations. There was a fishing tournament on Toledo Bend Reservoir on February 1 and a number of reports came in indicating that material was seen or heard falling into the water. The morning of February 1 was heavily fogged in and most of the reports from people on the water were classified as “ear witness” vice eyewitness. NASA and EPA began investigating these reports with the help of FEMA, the U.S. Coast Guard, and the Sabine River Authority. It was quickly realized that there was no way to simply locate and retrieve material that wasn’t visible on the shore and that an organized search effort would be needed to achieve results.

By February 4 additional assets arrived on scene including an FBI dive team with a Remotely Operated Vehicle (ROV), an EPA dive team, and a Texas Department of Public Safety dive team. Reports of debris sighted by helicopter were investigated. Even though the positions were thought to be accurate, search by boats and divers found no debris. By February 6 a Department of Justice tethered submersible was brought in, with EPA-contracted search assets following on February 7. During these first days, the organizations contributing to the water search included:

<table>
<tr><th>Dive Assets</th><th>Other Support</th></tr>
<tr><td>• Environmental Protection Agency
• Houston Police Department
• Federal Bureau of Investigation
• Galveston Sheriff's Department
• Galveston Police Department</td><td rowspan="3">• County Sheriffs
• Sabine River Authority
• Local Police and Fire Departments
• United States Coast Guard
• United States Coast Guard Auxiliary
• Louisiana Department of Fish and Wildlife
• Texas Parks and Wildlife
• Jasper County Emergency Services
• Texas Air National Guard</td></tr>
<tr><th>Search Assets</th></tr>
<tr><td>• Environmental Protection Agency
• Department of Justice
• Federal Bureau of Investigation</td></tr>
</table>

Even with these dedicated water search teams, NASA realized they needed expert help in organizing and managing the water search effort. NASA astronauts were guiding the dive teams, directing the search assets, and investigating reported sightings; none of which they were trained to do. Over the course of the week, the astronauts began looking for the expertise they needed to manage the water search.

The Navy received official tasking on February 13 and 14. The advanced party that had traveled with SUPSALV for the NASA and FEMA briefing on February 10 stayed on station in Lufkin and Toledo Bend, observed operations, and prepared for the equipment and personnel the Navy was ordering into Texas. During these initial days, they took stock of the talent and assets on hand and began to assemble an organization that could effectively search the two East Texas lakes for shuttle debris.

2.3 Water Search Organization

After SUPSALV arrived in Texas and received tasking to provide command and control to support the water search, SUPSALV organized the water team to take advantage of the strengths of the assets on the scene. The organization was divided into a Search Team and a Diving Team. An organization chart is included as Figure 2-1.

2.3.1 Search Team

Mr. Lee Wolford, a search specialist from NAVSEA 00C, coordinated the search efforts. The physical accomplishment of the search was the responsibility of Mr. Ridge Albaugh, a project manager from Phoenix International, the company holding SUPSALV's

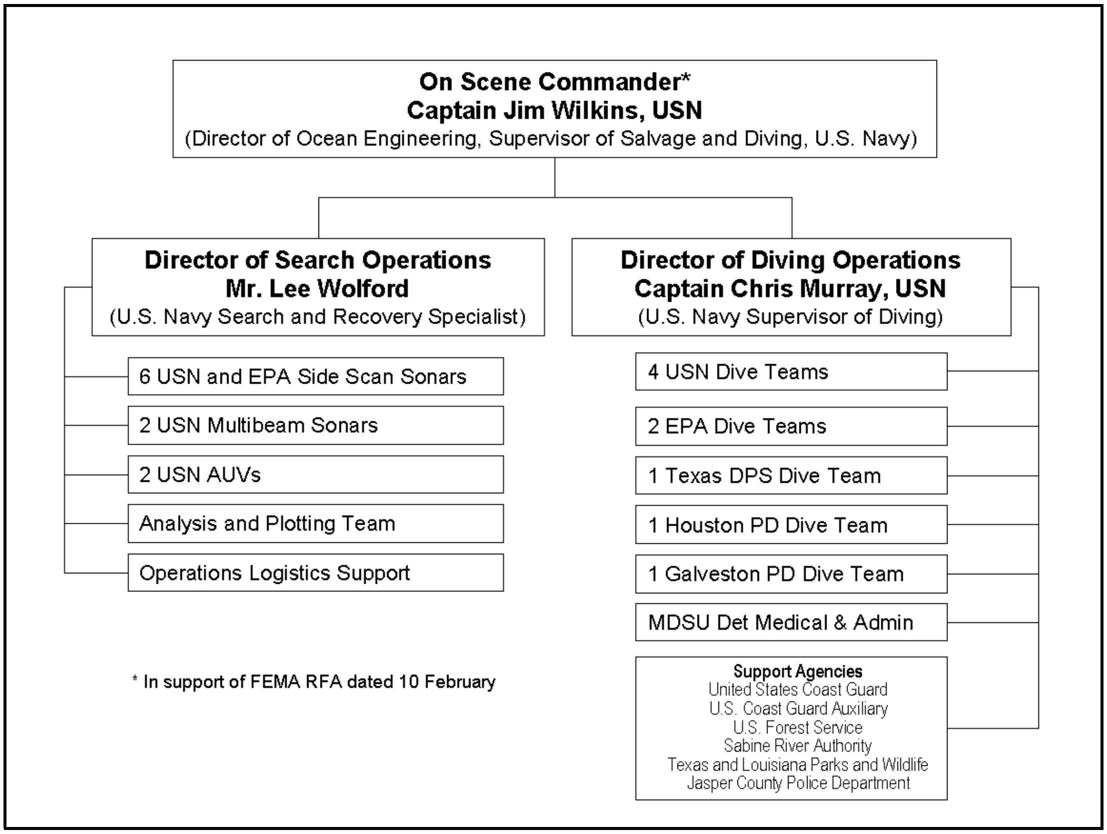


Figure 2-1. Columbia Water Search and Recovery Organization Chart.

Worldwide Underwater Operations contract. (This contract includes storage and maintenance of Navy-owned search and recovery equipment and provision of skilled labor to conduct searches and analyze search data.) The NAVSEA and Phoenix team managed the selection of assets, deployment of personnel, leasing of boats and gear, analysis of search data, generation of search lines for the next day, plotting of search data on charts of the lakes, and preparation of dive packages identifying targets for additional investigation by dive teams.

2.3.2 Dive Team

The Dive Team included divers from as many as five different organizations. CAPT Chris Murray, U.S. Navy Supervisor of Diving (SUPDIVE), managed this effort with Chief Warrant Officer Roger Riendeau of MDSU TWO assisting in coordinating the diving efforts. Non-U.S. Navy Dive teams dove according to their own agency's rules and regulations.

Search procedures were set by SUPDIVE using the best techniques and equipment from each team. Dive teams received their assignments (dive packages) each morning at the daily dive coordination meeting. At the end of the day, the dive teams returned the results of their dives to the Command Center where analysis was performed by the search analysis team. MDSU TWO personnel supported all dive teams administratively.

2.3.3 Security and Safety Support Boats

In addition to the search and diving teams, security boats were detailed to escort and provide a security buffer to all search and dive boats, protecting them from high-speed bass boats and interference by the general public. Security boats were outfitted with flashing blue lights to gain the attention of other boaters. Once on station, the security boats took position on either side of the search or dive area and waved off incoming bass boats. Security boats also assisted some of the dive teams by dropping buoys over targets and were available for use as a medevac to shore. There were as many as 12 security boats in use at any one time. All security and safety boats were coordinated and directed by the Director of Diving Operations.

2.3.4 Activities Involved

Over the course of the two-month long operation, a significant number of organizations, companies, and government agencies participated in the water search operation. The list of organizations involved and the nature of their support is provided in Figure 2-2.

2.4 Navy Mobilization

The Navy mobilization began on February 8 when Captain Jim Wilkins (SUPSALV) first spoke with NASA and EPA officials. A number of senior SUPSALV representatives and their Search and Recovery contractor arrived in Texas on February 9 and toured the area. On February 10 CAPT Chris Murray started to organize existing assets while awaiting official tasking and the arrival of Navy units from MDSU TWO. On February 13, the Navy received tasking to support NASA and put their plans into action. Both SUPSALV and MDSU TWO were tasked and responded independently.

Search Teams	Escorts / Support Vessels / Shore Aid / Shore Management
• Phoenix International • C&C Technologies (3 boats) • Innerspace Exploration Team (IET) • Lockheed Martin • Panamerican Consultants • Industrial Divers Incorporated • Navy Mobile Diving and Salvage Unit Two, Norfolk, VA (REMUS) **Dive Teams** • Houston Police Department Dive Team • Galveston Sheriffs Department • Galveston Police Dive Team • Navy Mobile Diving and Salvage Unit Two, Norfolk, VA • MDSU TWO Reserve Detachment 101 (Newport, RI), 409 (Cleveland, OH) and 608 (Jacksonville, FL) • EPA Dive Teams (Regions 3, 7, and 10) • Texas Department of Public Safety • Federal Bureau of Investigation	• Federal Emergency Management Agency • NASA • Environmental Protection Agency (On Scene Coordinator (OSC) and Environmental Response Team • Texas Air National Guard • Jasper County Sheriff • Jasper County Emergency Cooperative • Nacogdoches County Sheriff • Texas State Police • Louisiana State Police • Louisiana Fish and Wildlife • U.S. Forest Service • Bureau of Land Management • Sabine River Authority • Texas Forest Service • Texas Game Warden • Texas Parks and Wildlife • Hemphill Medical • U.S. Coast Guard and Coast Guard Auxiliary • Navy News • Coastal Systems Station, Panama City • National Oceanic Atmospheric Administration • C.A. Richards / Kongsberg Mesotech • Texas Department of Mental Health and Mental Retardation • Thales GeoSolutions (Pacific), Inc. • International Industries • ROH, Inc. • Fairmount Volunteer Fire Department • Six Mile Volunteer Fire Department

Figure 2-2. Participating Water Search Organizations.

SUPSALV's search assets were provided through Phoenix International, their search and recovery contractor. The SUPSALV and Phoenix team began arriving on February 14 and began to organize and execute a coordinated water search for shuttle debris.

By February 15, MDSU TWO divers and gear began to arrive from Norfolk, VA. The principal gear included two Light Weight Diving Systems (LWDS), a Transportable Recompression Chamber System (TRCS), two diving compressors, and diving gear to support four Navy dive teams.

Initially, the Columbia Diving Operations Command Center was located at the Fairmount Fire Station, but on February 26 the Command Center was combined with the Search Operations Command Center at a fishing resort called Fin and Feather Resort in Six Mile, TX. This facility provided accommodations for divers and search teams, dock space and a boat ramp, and office space to support the analysis of search data.

2.5 Coordination and Communication

Search Team and Dive Team coordination was vital to ensure the operation was conducted in a safe and professional manner. From the time of initial Navy involvement until February 26, diving operations were managed at the Fairmount Volunteer Fire Department Fire Station. Search management efforts and data processing began at the Six Mile Fire Station and moved to the Fin and Feather on February 14. These facilities were about 15 minutes apart and phone lines, at least initially, were in short supply so maintaining an effective line of communications was a challenge. To meet this challenge, Diving Management transferred to the Fin and Feather on February 26. This co-location eased some of the communications issues and supported the overall effort more efficiently. Another vital component of this operation was effective communications with the overall operation center in Lufkin, Texas. The support received from FEMA and the status reporting provided on a daily basis necessitated routine runs to and from Lufkin. CAPTs Wilkins and Murray traveled to Lufkin several times a week and NASA astronauts, EPA and FEMA officials were routine visitors to the Toledo Bend operations sites. Additionally, data was transferred to and from Lufkin daily via a satellite internet connection established by the Search Team and later upgraded to a land-based high-speed data line provided by FEMA.

MDSU TWO Chief Warrant Officer Roger Riendeau, SEA 00C's SUPDIVE, CAPT Chris Murray, and SEA 00C SUPSALV, CAPT Jim Wilkins held dive briefings each morning to provide each team with its assignment for the day. Dive packages were generated based on analysis of search data from previous days. The flow of information was not just from the search operations to dive operations, but both ways as each dive team reported the results of their dives. These reports were provided to the Dive Operations center at the end of the day and forwarded to the Search Operations center. This feedback was recorded into the search target database closing the loop on identified targets. During the morning dive brief, the teams were also informed of any known hazards, expected weather conditions, and emergency evacuation procedures in case of a medical emergency. On site NASA representatives provided specific guidance regarding potential shuttle hazards and analysis from other search assets.

Other meetings were conducted on an ad hoc basis. The following are two examples that represent typical ad hoc meetings. The first example was the search technique meetings that occurred after a day of operations or an analysis/test was conducted. After such an occurrence, a debrief was conducted with members of the Search Team, the Dive Team, SEA 00C, and the vendor or contractor's representative. Search techniques meetings were held on a regular basis at the beginning of the operation and only occasionally after the process and techniques became routine. Diver search technique meetings were initially held every 3-4 days and included all diving supervisors and dive team coordination staff. Lessons learned and best practices were discussed and put into effect.

A second example was one in which additional information was conveyed from NASA or as a result of analysis and evaluation of the utility of a particular search procedure. Generally, SUPSALV identified the nature of the new information and suggested that the key players develop strategy to utilize the information to their best advantage. For example, when NASA identified the trajectory of radar targets along with possible debris impact points, the Search Team evaluated the best method to ensure a thorough search was performed in that area. After the recommendation was prepared, the Search Team briefed SUPSALV and upon his concurrence, the process was incorporated into the daily routine.

Another form of communication was the routine briefing given to visitors. Often, FEMA, EPA, or NASA staff members would drive from Lufkin or Houston and get briefed on the status of the water search. Figure 2-3 is a photo of a brief given in the Diving Operations Center to a visiting NASA contingent.

Figure 2-3 Pictured at far left is Astronaut Jim Reilly, lead NASA liaison to the Water Search Team, briefing a visiting NASA contingent. Also pictured is NASA Administrator, Sean O'Keefe at far right and SUPSALV, CAPT Jim Wilkins, wearing Navy fatigues to right of center.

Meetings were held in Lufkin to coordinate the entire land, air, and water search efforts. SUPSALV attended these meetings each Monday to brief NASA on the Navy's water search and to learn the progress of the overall search effort.

2.6 Finance

On February 10, FEMA tasked the Navy to provide command and control functions and perform a water search of the East Texas lakes. FEMA's request for support was based on a jointly drafted tasking statement generated when SUPSALV initially visited East Texas on February 9 and 10. This initial tasking was based on a single day's tour of Toledo Bend Reservoir and a loosely defined requirement to search the reservoir and additional lakes, such as Lake Nacogdoches and any other lakes NASA might identify.

The assets available to SUPSALV included:

- SUPSALV salvage staff.
- SUPSALV search and recovery contractor (Phoenix International).
- SUPSALV Government Owned Contractor Operated (GOCO) equipment located in the Phoenix International warehouse in Landover, Maryland
- Diving assets including State and Federal agencies already on scene and Mobile Diving and Salvage Unit Two.

Based on this loose requirement, SUPSALV estimated $2.3M would be required to perform an orderly search over a period of about 4 weeks. When that figure was communicated to FEMA, a round number of $3M was agreed to. On February 10, FEMA forwarded their line of accounting which NAVSEA Contracts Division received without delay or difficulty on February 11.

After FEMA agreed to the estimate, SUPSALV issued a verbal Delivery Order to Phoenix International to mobilize for the search effort. Phoenix was standing by for tasking with their project manager already on scene in Texas getting ready for the team's arrival.

On March 7, FEMA asked the Navy to update their funding requirements to support an operation that would extend to April 30, 2003. Although NAVSEA had not come close to expending existing funds, they estimated that another $3M would be enough to cover the operation at its current pace through the end of April and cover any unexpected contingencies. FEMA issued these funds on March 17. They were received two days later.

With these funds, SUPSALV funded the following:

- Phoenix International staff, subcontracted search operation organizations, leased search equipment and boats, accommodations for nearly all of the water search organization at the Fin and Feather, daily inventory and equipment needs.
- Commander Naval Surface Force, Atlantic Fleet – reimbursement for operational expenses for the MDSU TWO detachment but not including salaries.
- ROH Incorporated technical writer who provided briefing support and prepared the final report.
- SUPSALV staff travel expenses and overtime funds.
- Naval Coastal Systems Station (CSS) provided search technique analysis input and a requested demonstration of LIMUS, which was considered for use by the divers (see Appendix A).

The Navy-led water search team wrapped up search operations on April 11 and completed diving operations on April 12. Demobilization efforts and reconciliation of FEMA assets took another couple of workdays. Complete operation expenses were expected to total less than the $6M authorized. On May 15, 2003, the final numbers totaled approximately $4.5M.

Operations

Section 3

Operations

The water search operations conducted by the Navy and other supporting organizations can be divided into two areas: search efforts and diving efforts. For this report, we will identify search efforts as those performed on the lakes by those who used sonar and bathymetry systems to scan the bottom for shuttle debris and by those performing analysis on the collected data and identifying diving targets. Diving operations consist of prosecuting the identified targets and the systematic clearing of the surrounding area at the dive site with diver-held search aids. This chapter records the tools and processes used to conduct these efforts.

3.1 Search Efforts

SUPSALV took over the water search operation on February 13 and conducted a systematic search of Lake Nacogdoches and Toledo Bend Reservoir over a 45-day period. Between the two lakes, the search area included more than 23 square miles of lake floor and resulted in identification of more than 3,000 targets. A timeline for the entire operation is provided as Appendix B. Daily Navy SITREPS were issued beginning on February 15 through the end of the operation on April 12. An example of these SITREPS can be found in the last pages of Appendix C.

3.1.1 Early Search Efforts

NASA, EPA, and FEMA mobilized on the day of the accident and by February 2, NASA and EPA had teams of engineers and search personnel on scene in East Texas. Eyewitnesses reported debris in yards, fields, and in other populous locations. As there was a fishing tournament on Toledo Bend Reservoir on February 1, a number of reports came in indicating that material had fallen into the lake. Due to heavy fog over the lake that morning, most witnesses did not see debris hit the water, rather they heard what was thought to be debris splashes. These eyewitness reports were classified as “ear witness” reports. NASA and EPA began investigating these reports with the help of U.S. Forest Service and Coast Guard resources and quickly realized that there was no way to simply locate and retrieve material that was not visible from the surface. In order to be effective, an organized search effort was needed.

By February 4, additional organizations arrived on scene including an FBI dive team, an FBI ROV, and a Texas Department of Public Safety dive team. Reported sightings were investigated from the surface and with assembled dive teams but no debris was found. By February 6, a Department of Justice tethered submersible was brought in and on February 7 EPA contracted search assets began to arrive. The initial plan by on-scene NASA astronauts was to put one search boat on the current shuttle debris line to run a gross survey and use the second search boat to run lines over the water in the vicinity of eyewitness sightings. On February 8, the water search team moved their headquarters from the Indian Mound boat launch site to the Fairmount Volunteer Fire Station. This move provided sheltered quarters to better coordinate activities around the lake. On February 10, following up on an eyewitness report, an FBI dive team retrieved one of the shuttle brake assemblies from the water on the Louisiana shore.

3.2 Navy Managed Search

The U.S. Navy's Office of Ocean Engineering, Supervisor of Salvage and Diving (SUPSALV) received tasking on February 13 to support the Space Shuttle Columbia water search efforts. SUPSALV tasked their primary search and recovery contractor, Phoenix International, on February 14. An advance party from SUPSALV and Phoenix had been on-site since February 9. Additional resources from Phoenix arrived in Toledo Bend with computers, plotters, search assets, sonar operators, and analysts to support the mission beginning February 15. After securing the Fin and Feather Resort as a base of operations, the SUPSALV-Phoenix team began evaluating the assets on-scene and the data collected to that point.

The Navy's initial search efforts were accomplished using Marine Sonic Centurion side scan sonar systems. The side scan units were employed by the Phoenix staff and EPA contracted teams.

After conducting a gross survey of the reservoir and recognizing the challenging conditions in the reservoir and on the bottom, SUPSALV began investigating alternative search assets that would allow them to penetrate the depths of the lake and see details through the trees and onto the bottom. The investigation, selection, and non-selection of assets was a process that continued from that first week of the operation with the recruitment of the Reson multibeam bathymetry sonar (operated by C&C Technologies under contract with Phoenix International), to the final two weeks of the operation with the analysis and consideration of a GeoPhex, a metal detector, to run in the shallows where the other sensors were unable to operate. This continuous selection process could be considered unique to this operation. It was a direct result of the fact that the debris being sought was quite small and thought to be widely spread out and that the conditions on the bottom were unusually cluttered. This section describes the selection process, the systems utilized, the systems considered, and some of the rationale for the choices.

SUPSALV conducted a number of tests that compared the utility of the equipment being used. Testing validated the equipment's ability to detect real shuttle debris (collected on land and provided for controlled tests), validated the ideal range and selected operating frequency of available sonar equipment. Tests also compared two different multibeam models, and validated the utility of the selected equipment against mock-ups of NASA's declared highest priority target at that time - the OEX Recorder. Details of this testing are provided later in this chapter. Full copies of the test plans and results are provided in the Appendices D, F, and G.

3.3 Search Management

Conducting an orderly search for debris required more than putting search boats on the water and turning them loose. Toledo Bend Reservoir and Lake Nacogdoches are large bodies of water and at one time there were more than 30 square miles of lake bed in the search field. The only way to perform an orderly search was to clearly define and reliably execute a tested search process. This section details the "management" of the search process.

3.3.1 Search Plot

The search team maintained a search plot that integrated the locations that they were tasked to search with the actual search lines, the targets identified, the targets cleared, and other inputs such as Ikonos satellite imagery or radar trajectory predictions. This search plot was the basis for ensuring the process was orderly and comprehensive. This section discusses the factors that influenced the search plot and the evolution of the plot over the course of the operation.

NASA initially specified that the primary debris "red" zone was a total of two nautical miles wide running from just south of Dallas in a east-southeast direction crossing the southern portion of Toledo Bend Reservoir. The water search plotting team plotted this search zone and broke it into lettered areas. These initial search zones were labeled A through L, covering 27 square nautical miles of water. On March 1 search zones M and N were added which encompassed areas with possible debris reported by eyewitnesses. This expansion to the south increased the total area to 32 square nautical miles and is represented by Figure 3-1.

At the March 3 briefing in Lufkin, CAPT Wilkins received guidance from NASA on the likely location of the highest priority targets. Based on this information, an update to the search coordinate plot was ordered. This plot re-focused the search right down the center of the February 20 NASA significant debris line. The heading for this line is approximately 118 degrees. NASA requested that a concentrated effort be made on the western end of the reservoir as the density of the recovered debris trailed off to the east. One exception was that a high priority search was directed to a location near the Louisiana coast where radar trajectory suggested debris could have fallen. The search plot was redrawn with a north and south boundary one nautical mile above and below the NASA significant debris line. This newly established search zone was compressed to 14.69 square nautical miles.

On March 18, NASA evaluated SUPSALV's progress and asked that the Navy plan to complete their search by April 15. Given this new ending date and a refined definition of the search area, the Navy was able to plan to complete the assigned task with a high degree of confidence. SUPSALV determined that there was sufficient time to fully cover the deep, heavily forested, central portion of the lake with the two multibeam systems and complete all the edges, coves, and shallower portions with the remaining side scan systems. This division of search assignments was based on the fact that the side scan systems were best suited for running close to the lake bottom and the trees in the water column prevented deepwater employment in their proper configuration. On the other hand, the multibeam systems, due to their surface mount and fixed beam width, were best suited for deployment in deeper sections of the lake. Figure 3-2 represents the Toledo Bend search area broken into multibeam coverage and side scan zones.

Given the ability to operate until April 15 and understanding that NASA was observing that a higher percentage of significant debris was recovered north of the debris line, the search area was expanded to include a 0.5 mile section to the north of the primary search area. This expansion was also searched using the side scan in shallow water/multi-beam in deep water process that was proven effective earlier in the operation. In addition

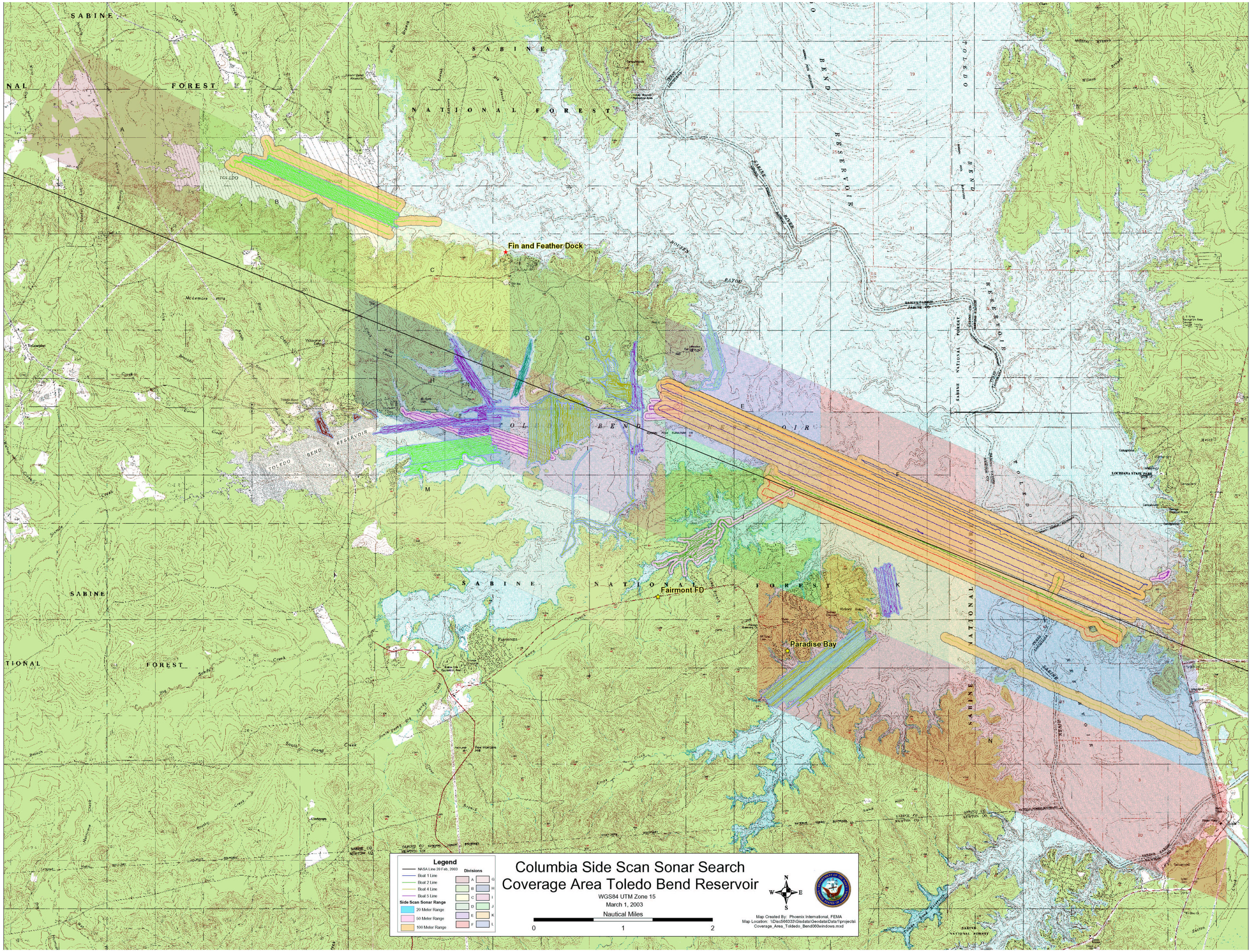


Figure 3-1. Toledo Bend Initial Search Plot Dated March 1, 2003

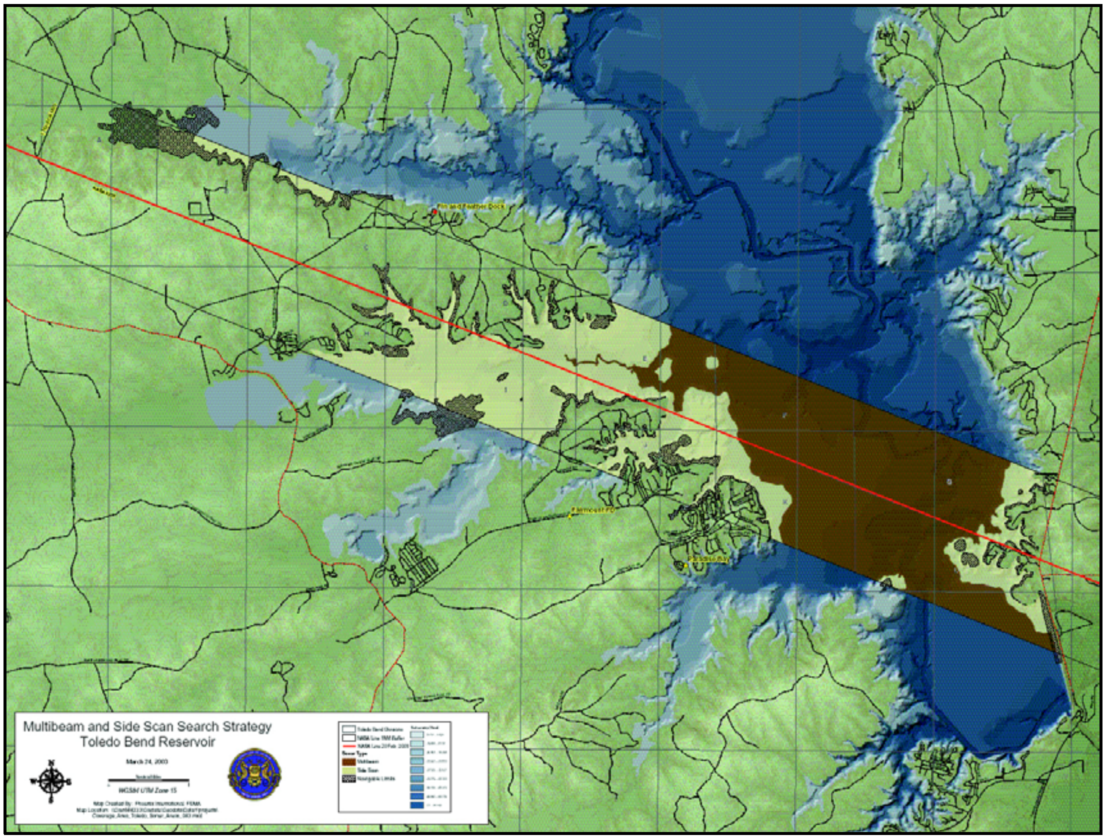


Figure 3-2. Toledo Bend Search Assignments. Multibeam coverage areas are shown in brown, sidescan in light green.

to this new 0.5 mile search zone, NASA added two new search zones based on specific intelligence. The first was a new target area that was based on the finding of two pieces of a camera on land. A line drawn connecting those locations crossed two small bays of Toledo Bend (6 Mile and Sandy Creek). Hoping to find the camera itself, the water search teams searched these areas on April 10 and dove on them on April 11. The second new area was added based on an eyewitness report. A V-shaped area was added in the north-west part of the search area. The eyewitness saw a piece from a distance, but was not sure if it landed in the water or on land. The V-shaped area was scanned on April 10 and 11 and divers went into that area on April 11 and 12. The Navy teams completed the initial search area, the additional 0.5-mile area to the north, and the two new search zones by April 11. Figure 3-3 represents the final search plot for Toledo Bend Reservoir dated 12 April 2003. It also shows the eyewitness search points, the trajectory prediction locations, and other debris locations near the reservoir.

The boats equipped with Marine Sonic Centurion sonar systems were capable of searching in 20-meter, 50-meter and 100-meter range scales. To get a quick under-standing of the reservoir bottom, a 100-meter search was conducted across the "red" zone. Afterward, lines were plotted and provided to the search boats to support 20-meter range searches where possible. The 20-meter range scale performed best in creeks, coves, and other areas where depth of water supported close in work. At this range, the search managers plotted lines approximately 15 meters apart, allowing the boats to scan the unsurveyed space directly under the previous pass with the next pass. At the 20-meter range, one pixel equals 6 inches on the bottom therefore minimum size that could be distinguished is 4 pixels (1 ft^2). In reality, material closer to 0.5 square meters (2.6 ft^2) in size was the minimum practical target. A sample of the lines Marine Sonic sonar recorded is provided in Figure 3-4.

3.3.2 Navigation

Accurate location and position information is key to a search and recovery operation. During the Columbia operation, the search and recovery teams had exceptional assets available to ensure the data and diver location information was as precise as possible. Phoenix International placed C&C Technologies under contract to provide both search assets and advanced GPS technology. C&C Technologies, who supplied and crewed three of the search boats, was able to provide sub-meter survey grade navigation positioning through their C-Nav differential GPS system. To take advantage of this capability, a plan was developed to validate individual team navigation systems. C&C established four known points around the Toledo Bend Reservoir: two were tree stumps protruding from the lake, one was at Paradise Cove fuel dock, and one was at the Fin and Feather Resort launch pier. Each day the buoy drop boats and dive team boats verified their navigation equipment, normally Trimble GPS systems, with the known position at the beginning and at the end of the day. Over the course of the operation, additional C-Nav differential GPS systems were obtained and fitted out on all the search boats.

A second aid in correlating target data with potential non-shuttle debris topography was the overlay of 1960 aerial photographs on the existing chart plots. This resulted in an overall view of pre-reservoir landscape, including man-made structures that remain under the water surface. Figure 3-5 is a nautical chart of Toledo Bend overlaid with aerial photography providing clues to existing bottom conditions.

Critical to the navigation/positioning process was the correlation of side scan and multibeam targets to an exact geographic position. This integration was accomplished through the computer program - WINFROG. WINFROG also provided steer-to and course correction information to the helmsman who was running a predetermined set of lines. WINFROG is a MS Windows-compatible navigation software created by Thales GeoSolutions (Pacific), Inc. of California.

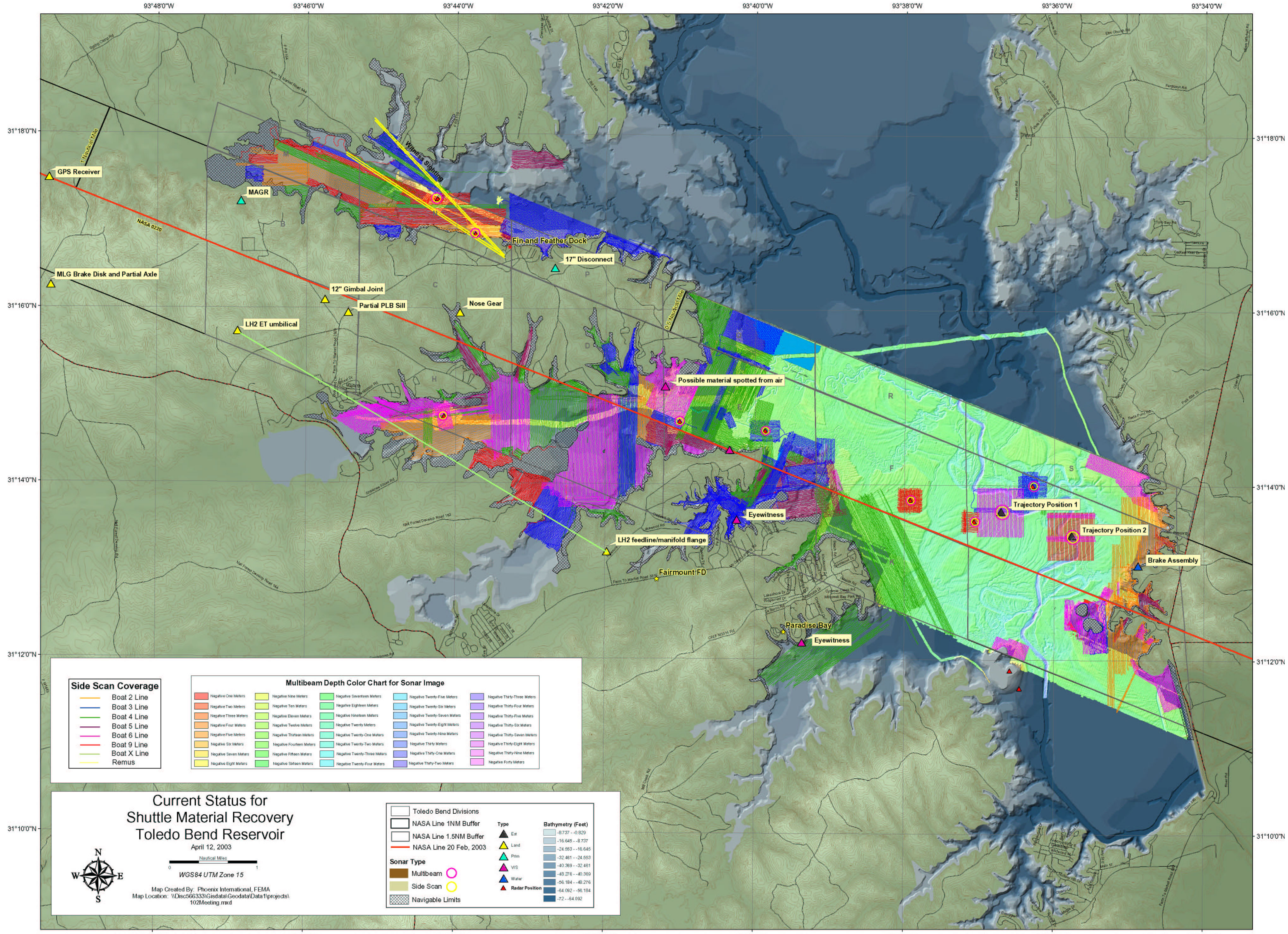


Figure 3-3. Toledo Bend Final Search Plot Dated April 12, 2003

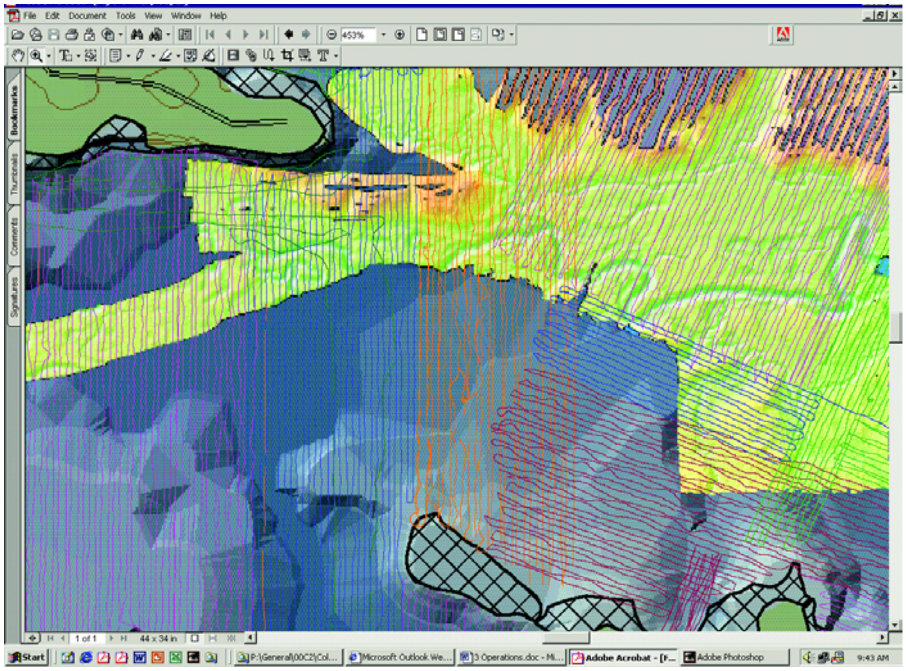


Figure 3-4. Plotted Marine Sonic Side Scan Lines, Toledo Bend.

Back in the lab, the boat, and sonar data positioning information needed to be correlated to a geographic plot. This was necessary to ensure complete coverage of assigned search areas and to position potential targets accurately. Phoenix arrived in Toledo Bend with experienced Geographic Information Systems (GIS) operators and software. They established the search coordinates and developed large scale plots for operations management and small scale plots for diver target packages.

A significant resource available to the search coordination team was the loan of GIS operators made available through the federally operated Geographic Area Coordination Center (GACC). GACC was tasked to support the project by FEMA RFA and was able to draw upon GIS resources from the Bureau of Land Management, U.S. Forest Service, and National Park Service. Typically two “loaner” GIS operators worked with two or three Phoenix GIS operators to plot the previous day’s search results and generate the next day's search and diving assignments. The Federal GIS operators obtained their experience in support of forest fire fighting teams while Phoenix’s operators have been trained under SUPSALV contract to support extensive deep ocean search operations.

NASA provided Ikonos satellite imagery (a Space Imaging Corporation product) to the water search team. These images provided a 10-centimeter resolution picture of

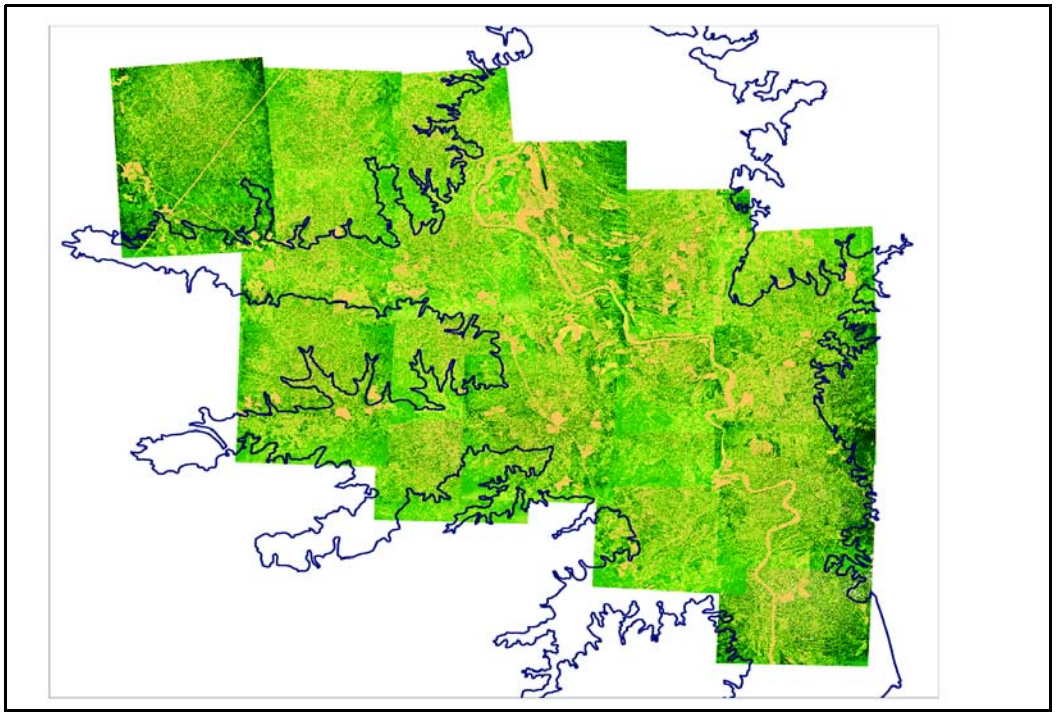


Figure 3-5. Toledo Bend Overlaid with Pre-Flood Aerial Photography.

the reservoir a day or two after the shuttle went down. NASA used this imagery to provide location information on items that could be shuttle debris. Ikonos imagery was predominately used to support the ground search effort but the water search team also used the imagery for items depicted in very shallow water that were identified as potential shuttle targets. These potential targets were plotted on the search charts and treated as high priority targets.

3.3.3 Data Analysis and Management

Search data was largely analyzed during the 7PM to 7AM shift. As the operation grew, additional analysts were brought in and a number staffed the day shift as well. After the search boats returned each day, the sonar data was copied from the search boat's computer to a CD. Since the search process was very data intensive, the data transfer often involved cutting as many as 12 CDs from a single boat's daily run. Later in the operation, removable hard drives were obtained for a number of the boat PCs that allowed much faster data transfer to the analysis lab. When Lake Nacogdoches was being searched, a driver was sent there at the end of the day to collect the Klein and Marine Sonic data.

The sonar analysts were principally Phoenix's most experienced sonar operators. Each sonar system that was put on line required an additional analyst to keep up with the volume of data that was generated.

The Marine Sonic side scan sonar data was broken into files covering the width of the swath by approximately 80 meters long. This segmentation avoids the generation of overly large files. Operators open a series of sonar plots, scanning each one completely before opening the next. The sonar return imaging was reviewed to identify possible shuttle debris. The data evaluation was challenging because, even though the bottom conditions varied, much of the reservoir floor was covered with standing and fallen trees. Stumps provided sonar return that was bright and small and only the shadow length distinguished them from possible shuttle targets. Given the expected small size of possible shuttle debris, the shadows cast by the trees and stumps could very easily hide debris. To reduce the chance of this, the search management team specified that the side scan boats run lines at a 15-meter spacing to ensure the bottom was scanned from both the left and the right. In some high priority areas, when time permitted, search lines were plotted at right angles to each other, again doubling the coverage. An example of the imagery produced by Marine Sonic sonar in Toledo Bend is shown in Figure 3–6.

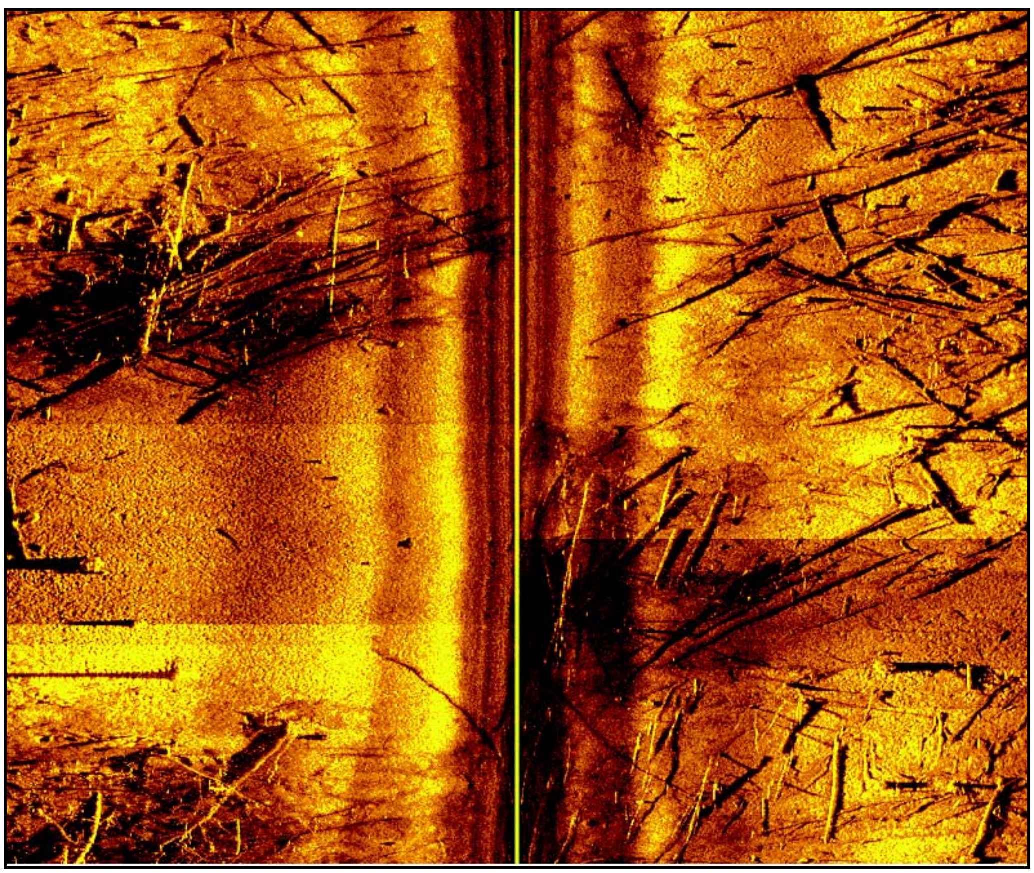


Figure 3-6. Typical Imagery from Marine Sonic Sonar in Toledo Bend.

Based on the nature of the debris recovered on land and feedback from the divers who reported results on their previous day's search, the analysts adjusted their focus. They attempted to rule out stumps, even though they provided strong returns and tried to identify sonar returns that were box-like in shape or any flat, high-return objects that were irregular in shape and generally less than two square meters in size. When an item of interest was noted, the operator recorded the target data into an Excel spreadsheet. The recorded data included Julian date from the search lines, latitude and longitude in degrees and decimal degrees (minutes and seconds converted to decimals of degrees), file name, depth of tow, and comments including measured size of target and heading of tow fish.

Feedback was provided each evening. When the dive teams returned, they provided the results of their dives recorded on their individual dive packages. The diver annotated each target, describing what was found on that target. This feedback process helped the sonar analysts learn the nature of the sonar contacts and improved the selection of likely targets.

Initially, all of the searching was conducted with Marine Sonic side scan sonar systems. Because of the challenging conditions encountered, the Navy identified additional resources for use in the lakes. By February 26, a Reson multibeam bathymetry sonar was brought in to search the deeper section of Toledo Bend Reservoir and a Klein 3000 side scan sonar was being used in the clearer sections of Lake Nacogdoches. These systems generated unique forms of data and the analysis was handled slightly differently. Multibeam data is recorded in raw form but is processed to eliminate noise and manipulated to display results in a number of formats. Results with detail as fine as 20-centimeter resolution can be achieved with its 240 beams, each ½ degree in width, which are transmitted simultaneously. Swath width is dependent on water depth, with width being approximately 3½ times the water depth. The multibeam provided excellent bottom mapping capability and appeared to be the best tool to use when the depth of the water (dictating a deep sidescan tow) conflicted with lake conditions containing tall trees and stumps (dictating a shallow sidescan tow). The multibeam was also effective in cross-checking the nature of specific debris recorded by a side scan unit. The sonar analysts found that bottom debris was best observed using the multibeam data in pseudo side scan mode. If an item of interest was noted, the analyst could employ a bathymetry display to allow target discrimination and refinement. Figure 3-7 is an item of interest noted using Reson multibeam in pseudo side scan mode.

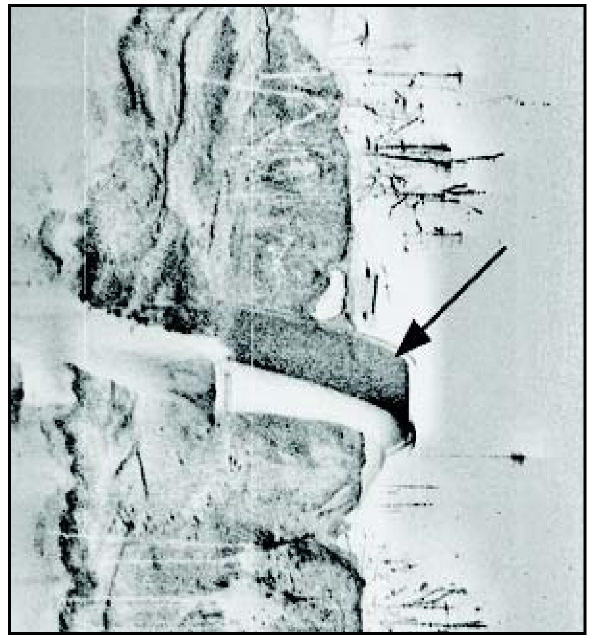


Figure 3-7. Pseudo Side Scan Imagery-showing a selected diving target.

The Klein seemed to offer higher resolution imagery and could be effectively used at a longer 37-meter range scale to detect small targets. This higher range allowed its use in deeper sections of the reservoir and extra coverage in shallow areas.

3.4 Search Techniques, Assets, and Data Analysis

3.4.1 Selection of Assets

SUPSALV organized the search for shuttle debris using a diverse combination of systems. The hostile nature of the Toledo Bend Reservoir required systems that could detect and distinguish man-made items as small as the OEX recorder, yet tough enough to survive the knocks encountered when searching through tree and stump-filled waters. Another consideration was the vessels available on the lake. There were no platforms on the lake that could support a large system such as SUPSALV's Orion and the depth of the lake did not require a system that large.

Side scan sonar is an established method for conducting underwater searches and it was the first method SUPSALV brought to the scene. The side scan method involves using narrow beams of acoustic energy (sound) transmitted out of the side of the towfish to the bottom of the sea/lake bed. Sound is reflected back from the bottom and from objects on the bottom to the towfish. Frequency selection is task dependent. High frequencies with narrow beams widths, such as 500 kHz to 2.4 MHz, give excellent resolutions of objects, small and large, but the acoustic energy only travels a short distance. Lower frequency systems travel longer distances but have decreased ability to find smaller objects. Two of the primary systems used in Toledo Bend and Lake Nacogdoches were side scan sonar systems. The third was a bathymetry system. The employment of each of the systems used for the operation is described below. Additional information on the systems is included in Appendix A.

3.4.1.1 Marine Sonic Centurion Side Scan Sonar

A total of five Marine Sonic Centurion side scan sonar systems were used in the water search (3 on-scene plus 2 brought in by SUPSALV). The U.S. Navy search on Toledo Bend Reservoir began with a 100-meter gross survey using the Marine Sonic sonar to obtain a feel for the reservoir bottom topography and nature of the sonar return on the bottom. Based on the results, it was decided that a more detailed search was needed but it was also noted that the trees extending off the bottom of the lake were going to present a significant challenge to the search teams. The majority of the remaining searches using the Centurion was conducted using 20-meter range scale. Figure 3-8 represents the typical configuration of the Marine Sonic sonar used in Toledo Bend.

Marine Sonic sonar operates at a number of frequencies. Some at 300 kHz and 600 kHz, others at 900 kHz, 1200 kHz, and 2400 kHz. It was noted that the custom 600 kHz sonar (operated by Innerspace) had the transducers physically turned down to a 10-degree angle vice the stock configuration of 5 degrees. This focused more of the energy under the fish and less at the range limits. Since the boats often had to tow their fish above the optimum depth due to the number of trees in the water column, the custom 10-degree Marine Sonic sonar generated better images than the same frequency 5-degree fish. After proving this in formalized testing, all stock Marine Sonic sonars were taken out of service on March 17. This was possible because SUPSALV had a sufficient number of other systems that were effectively supporting the operation.

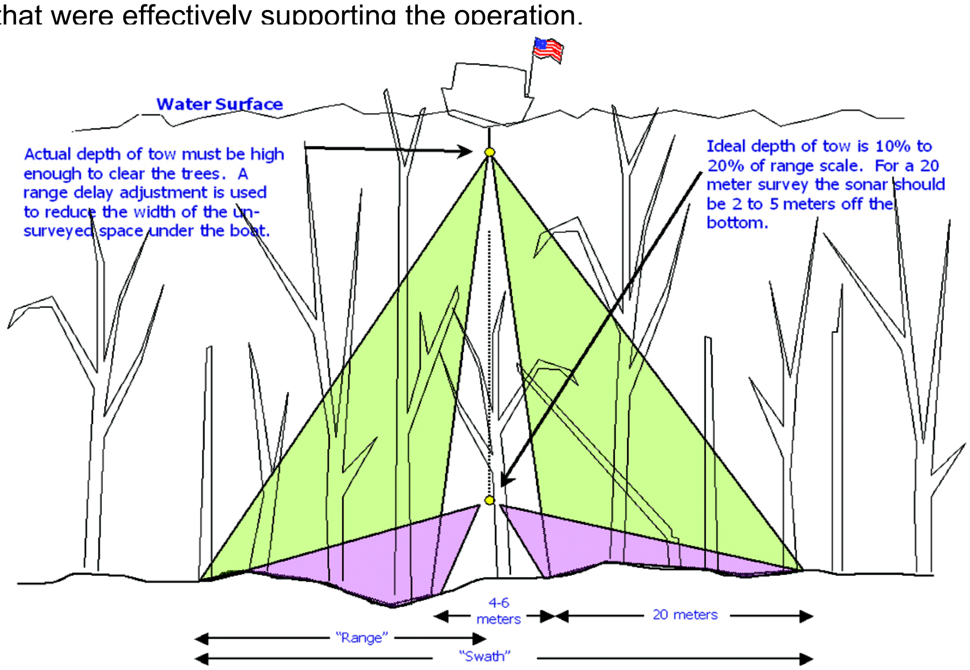


Figure 3-8. Typical Side Scan Sonar Configuration.

3.4.1.2 Reson Multibeam Bathymetry Sonar

A second search asset used on Toledo Bend Reservoir was the Reson Seabat multibeam bathymetry sonar, model 8125. This unit generated both bathymetry soundings and sidescan imagery operating at 455 kHz. The multibeam sounds down with a 120-beam pan beam with amplitude and phase time series that returns 240 one-half degree soundings. The beam produces returns approximately three and a half times wider than the distance between the transmitter and the bottom. In 12 meters of water, the swath of coverage is approximately 40 meters wide. Since there is no un-surveyed space under the boat, each following line can be plotted with spacing nearly equal to the swath width. Figure 3–9 provides a sketch of the multibeam search configuration on Toledo Bend. The return is raw data vice imagery and requires post-processing for evaluation.

For operations on Toledo Bend, the multibeam unit had the transmitter (cylindrical) and receiver (rectangular) mounted on a sliding rail. This was tilted forward until the unit was facing straight down and the rail was aligned vertically. Transceiver protection was provided by large metal guard bars that were installed in front of the transceiver. A

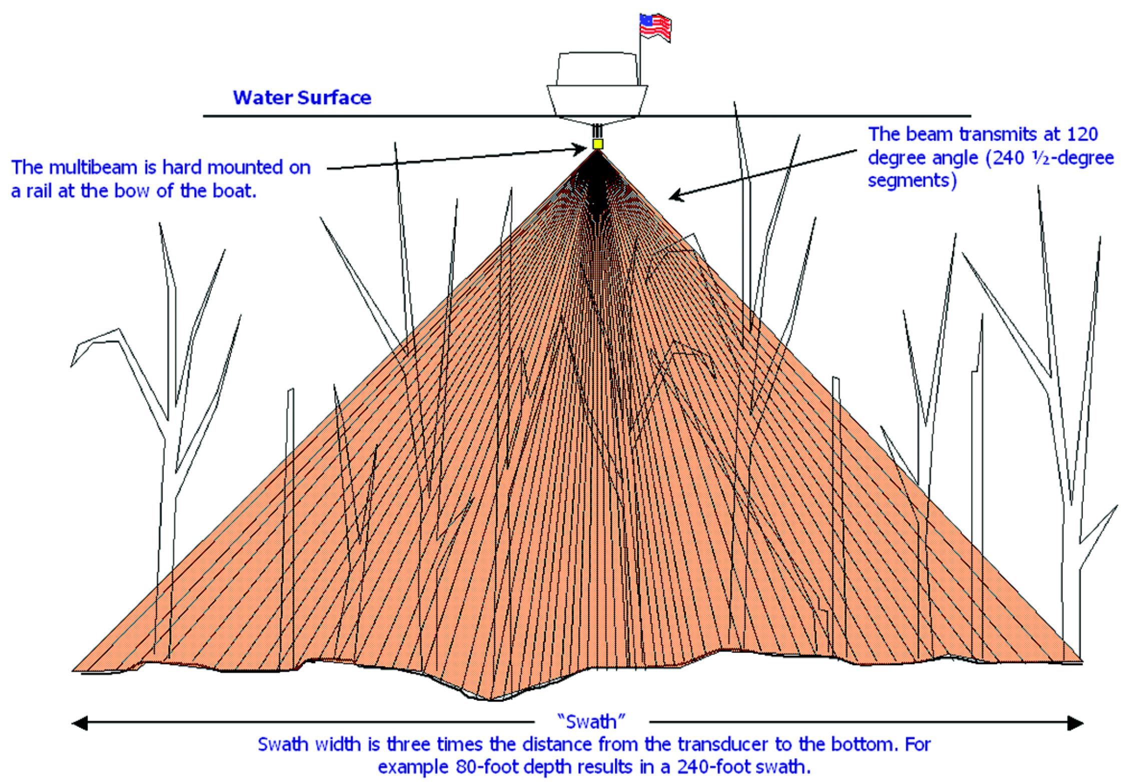


Figure 3-9. Representation of Multibeam Search Operations.

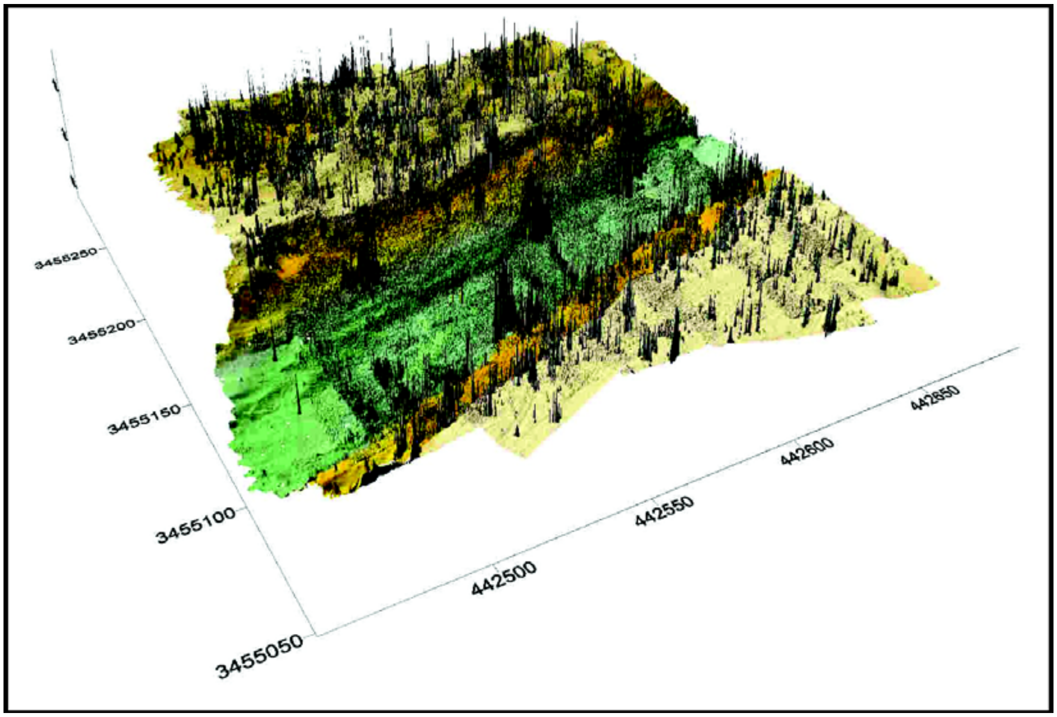


Figure 3-10. Multibeam 3D Representation of Bottom Bathymetry.

secondary protective measure used was the swinging vertical mount secured with shear pins that would break if contact was made with a large object. During one survey line in a stump-filled portion of the reservoir on February 27, the team reported hitting 10 submerged objects, five of which broke the shear pin.

The multibeam generated raw data that was analyzed ashore in order to "see" what was on the bottom. Figure 3-10 is a three-dimensional representation of a section of the reservoir floor. It was described as if someone took a sheet and draped it over everything that was on the bottom. The 3D model is the resulting image. The analysts set up interactive images that they were able to "fly" through as a tool in their search for targets. Figure 3-11 represents a still image of one of the 3D scatter plots.

The multibeam was considered useful for two reasons. It provided high resolution data that was able to identify man-made objects and unique shapes on the bottom and it looked down into deeper waters where tall trees prevented use of conventional sidescan sonar systems.

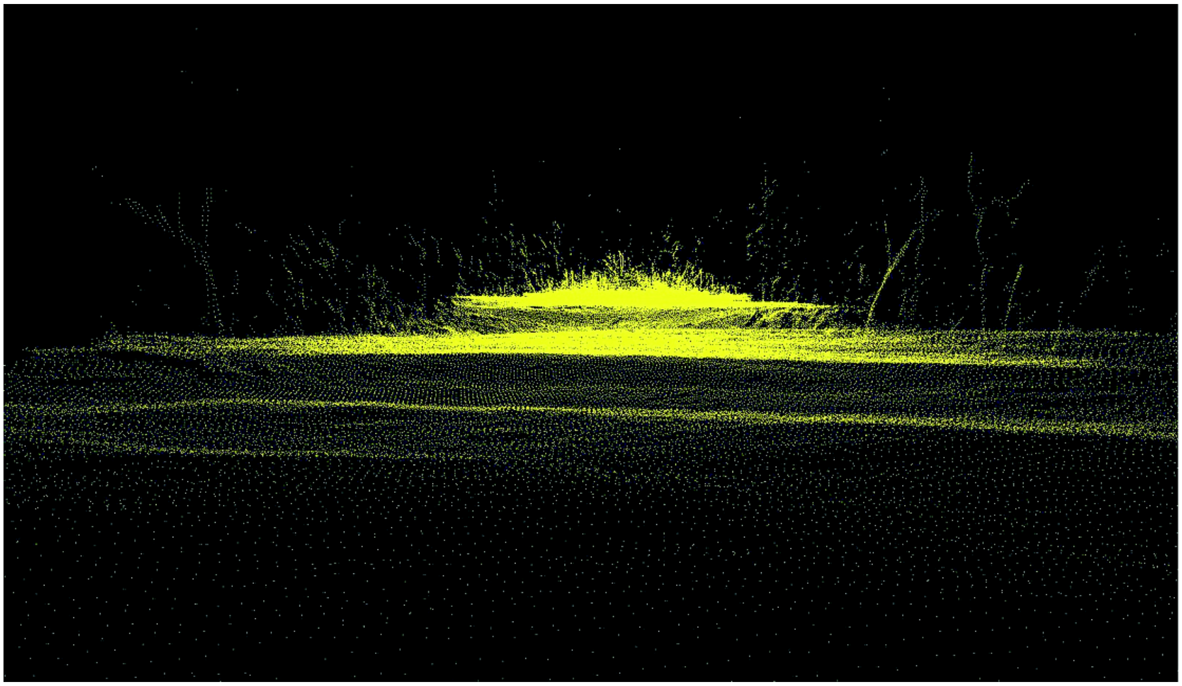


Figure 3-11. Multibeam 3D Scatter Plot.

To improve the usefulness of the bathymetry tools, a number of steps were taken. The first was to try to improve and enhance the imagery output. To do this, SUPSALV requested that Quester Tanget, a firm that specializes in classification of the sea floor, look at Toledo Bend multibeam bathymetry data and see if there was a way to filter out trees and stumps through post-processing, leaving only non-wooden or man-made targets. After analysis of actual bottom data, Quester Tanget indicated that they knew of no way to improve the post processing process to highlight the man-made objects.

The second step taken to achieve greater accuracy in target identification using the Reson Seabat 8125 was to contact Dr. Larry Mayer and Dr. Brian Calder of the Center for Coastal and Ocean Mapping, University of New Hampshire. The UNH team came to the Toledo Bend Reservoir search headquarters to help with the evaluation of current practices aimed at identifying and recovering wreckage from the Space Shuttle Columbia. Prior to their arrival, Dr. Mayer was forwarded sample 8125 data to examine and determine whether it was possible to alter the scanning software to increase target detectability. Dr. Mayer and Dr. Calder focused on developing a multibeam sonar processing protocol to maximize the chances of identifying small targets in the cluttered environment of the reservoir. The fundamental question was whether the 8125 could resolve targets the size of an OEX recorder (7.5 in. x 17 in. x 22 in.). Even if it was determined that the sonar could resolve a target of this size (using bathymetry, imagery, or both), the next issue was whether anything could be done to improve the probability of detecting a real target in the context of the complex reservoir floor. To improve the target detection capability, an attempt was made to remove clutter caused by larger targets (tall trees). Dr. Calder modified his CUBE (Combined Uncertainty and Bathymetry Estimator) algorithm in an attempt to remove features attached to the reservoir floor over two meters in height. Details of this analysis are provided as Appendix E. After thorough evaluation, it was decided that the CUBE process, although useful, was too cumbersome for large area searches. SUPSALV elected to use the CUBE process only as an additional aid in classifying a target.

3.4.1.3 Klein 3000 Side Scan Sonar

After taking a gross survey of Lake Nacogdoches using a Marine Sonic sonar, SUPSALV began looking for search assets that could support a more detailed search of the lake. Conversations with staff at the U.S. Navy Coastal Systems Station in Panama City, FL led to discussion about using Klein sonars. These systems are known to perform fast surveys with high quality data. Conversations with Klein Associates, Inc. led to consideration of their newest model, the 3000 which offered substantially the same technical performance as the Klein 5000 Side Scan Sonar. This unit is small (less than four feet long) and provides very high quality data. One additional advantage is that the data is available in raw format and supports post-processing enhancement.

Phoenix obtained a Klein 3000 from International Industries of Annapolis, MD on February 26 and a detailed survey of Lake Nacogdoches was ordered. With this sonar, a plot was drawn at 30-meter spacing for running a 37.5-meter range scale search. With the boat averaging 3 knots, the quality of the data was exceptional. On February 28, a second boat was brought in to continue the Lake Nacogdoches survey. This boat was equipped with the original Marine Sonic sonar and concentrated on the edges and shallower sections of the lake. The Klein continued its survey, running on two axes of the first mile wide “red” zone. On March 3, the vessel was moved south to survey the deeper section below the NASA line, while the Marine Sonic Sonar continued to search the shallower portions east and west of the Klein survey lines, as well as the north section. Figure 3-12 is an example of the imagery the Klein 3000 produced.

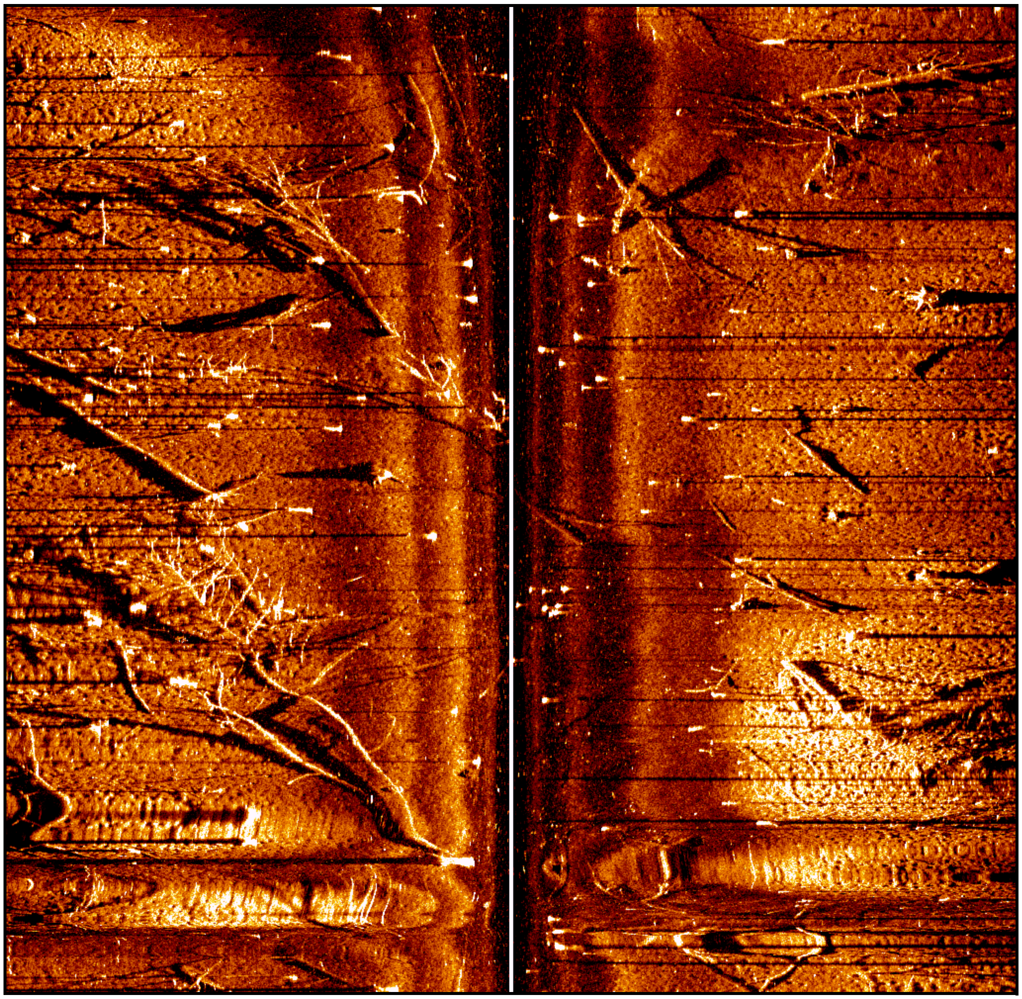


Figure 3-12. Example of Klein Imagery.

Since the imagery produced by the Klein 3000 proved to be very productive, SUPSALV began planning to move the Klein to Toledo Bend Reservoir after the survey of Lake Nacogdoches was complete. Part of this planning included confirming that the Klein was being utilized in the best configuration possible given the size of the high priority target. On March 8, two of the team's sonar experts who had performed an evaluation on Klein system presented their results. Their report provided optimization information that supported selection of the 37.5-meter range scale and boat speed of 2.5 knots. The report also identified the smallest target that could be detected given the conditions in the lake. This report is provided as Appendix F.

The Klein 3000 system was redeployed to the Toledo Bend Reservoir on March 10. During controlled testing conducted on March 16, the quality of the Klein imagery was confirmed and a second Klein was sought. This Klein, also obtained from International

Industries, arrived on March 19 and began its survey on March 22. A third Klein was obtained from the State of Georgia, Department of Natural Resources and arrived on March 27 for use on Toledo Bend Reservoir.

3.4.1.4 Remote Environmental Monitoring Units (REMUS)

REMUS is an Autonomous Underwater Vehicle (AUV) equipped with a Marine Sonic sonar that operates at a frequency of 1200 kHz. REMUS was considered for two reasons - it is a Navy-owned asset which could be deployed at limited expense and it is able to conduct autonomous operations. It was hoped that, because it was not tethered to the surface like conventional towed sonar, it could run through the trees as opposed to running over the trees. Figure 3-13 is a depiction of the REMUS operation.

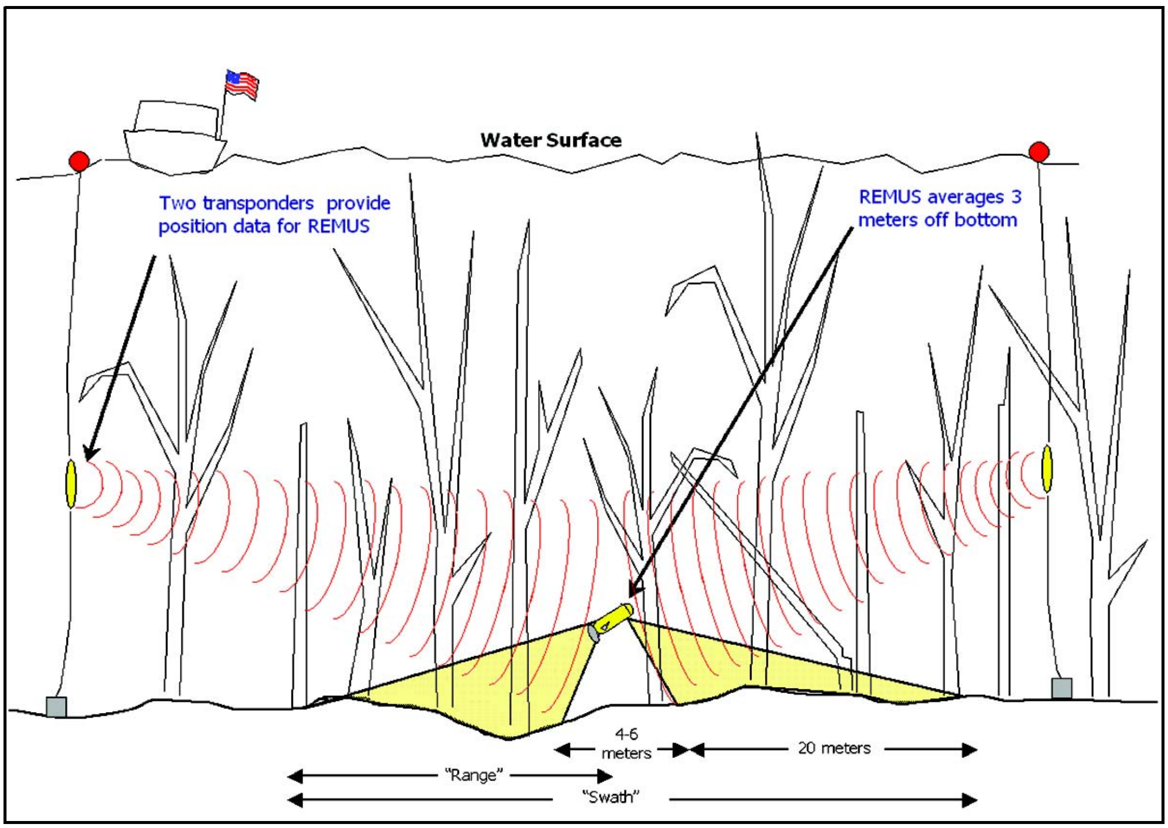


Figure 3-13. REMUS Operations.

REMUS was used in a number of environments on Toledo Bend Reservoir with mixed results. Although it had a ground tracking capability, which supported running at a consistent level above the bottom, the operators found that it was unable to adjust for the extreme diversity in the lake bed and often ran into the back side of a lake bed stream bank. It also had such a light propulsion system that it could not power through the dense grasses that were encountered in some areas of the reservoir. Although REMUS was able to complete its runs in open areas and provide very clear and detailed images, REMUS was unable to track its position consistently. As this position information was unreliable and made diving on a REMUS-based target difficult, SUPSALV contacted LT Ben Evans of the Office of Coast Survey (NOAA) to evaluate the process and offer ideas on how the REMUS could be used more effectively. LT Evans' suggestions included:

- Use only one REMUS in an area. Two REMUS in the same area allow the possibility of the transponders and transducers confusing each other. Each transponder will transmit to both REMUS transducers.
- Use four transponders instead of two transponders to provide location data. The fish will choose the transponder that provides the best fix.
- When the REMUS rejects one of the transponder's signal, it runs a DR (dead reckoning) path until it accepts a new fix. At that point, its assumed position is shifted from the DR location to the true position. Some of the earlier tracks showed a 50 or 100-meter shift which made the position of any contacts located on that run difficult to find. It was suggested that using 4 transponders that were 250 yards off the survey could reduce the location shift to as little as 10 to 15 meters. After Woods Hole engineer, Tom Austin, arrived and conducted an analysis, he indicated that this should not have been necessary. It appeared that the transponder signal were multipathing due to the challenging acoustic environment in the lake.
- Location of the transponders was not assured by the method the REMUS technicians were using to drop the transponders. It was recommended that they approach the intended location, drop the clump, then pull the line vertical and hit the Man Overboard (MOB) button on the GPS. The GPS should either have an external antenna or be placed outside of the boat cabin to improve the quality of its signal.
- LT Evans recommended contacting a Woods Hole (WHOI) representative to review the location issue and get suggestions for improving the process.
- Use REMUS in clear waters like the lake shore north of the Fin and Feather. This would give REMUS the best chance to contribute to the operation even if searching areas outside of the primary search zone.

As suggested by LT Evans, SUPSALV contacted WHOI to provide field evaluation and attempt to resolve the positioning issues. On March 28, the decision was made to terminate use of REMUS for the Space Shuttle Columbia recovery operation. Between navigation problems and the constant search and recovery required to bring REMUS home at night, further use of REMUS was limited in this mission.

3.4.2 Search System Testing

Tests were conducted over a two-week period during the operation to ensure the equipment being used was able to achieve the expected results. SUPSALV ordered the first series of tests on March 2 as the water search organization had yet to find any shuttle debris. NASA provided 4 pieces of shuttle skin material that had been recovered on land for controlled testing. The dive team tied these pieces to buoys and dropped them in approximately 20 feet of water in a relatively clear bottom in front of the Fin and Feather. These pieces ranged in size from the largest being 1 by 2 meters to the smallest measuring 0.4 by 0.5 meters. See Figure 3-14 for photos of these shuttle pieces. Search boats operating both multibeam system and a Marine Sonic side scan ran the test range. It was noted that detection of the largest target was possible, while detection of the smaller targets was uncertain.

Figure 3-14. Actual Shuttle Pieces Used a Test Targets.

A second test was initiated on March 6 when a second Reson multibeam was brought in. The second multibeam system arrived with both 8125 and 8101 heads. SUPSALV needed to determine which system returned the most useful data. A variety of metallic items thought to be a rough approximation of shuttle debris was selected from a local landfill for testing. These included a metallic punch clock, a 12-quart coffee urn, a steel PC housing, and some sheet metal roofing material. A test plan was developed which designated the requirements for the bottom topography, gave the divers criteria for placing the test material on the bottom, and identified the search techniques to be used. After completing the test runs on March 6 and 7, analysis of the processed data revealed that because the 8125 provided higher resolution data, its ability to distinguish smaller and medium sized objects was greater given the same range scale. To keep the 8101 resolution useful, the effective swath width was reduced to about 10 meters compared to 30 meters for the 8125. The testing revealed that the smallest of the test targets was on the very edge of the detection range of the 8125. This testing confirmed that the Reson 8101 Multibeam was going to be of limited use in identifying small objects. Based on this analysis, the 8101 head was removed and the second Reson Multibeam 8125 was put in service. Detailed results of the comparison test are provided in Appendix D.

Based on the difficulty encountered in seeing the test material in the two previous informal tests and given the fact that NASA had identified the OEX Recorder as the highest priority search target at the time, SUPSALV initiated a more formalized test plan to determine if the search systems on-scene were able to locate and detect an object the size of the OEX Recorder (22 inches x 17.5 inches x 7.5 inches). A number of side scan and multibeam experts were brought in to conduct these tests. They included: Mr. Pete Alleman from C&C Technologies, Drs. Larry Mayer and Brian Calder from the Center for Coastal and Ocean Mapping at the University of New Hampshire, and Mr. Doug Lockhart from Thales.

On March 11 the experts met with CAPT Wilkins, CAPT Murray, Ridge Albaugh, Lee Wolford, and NASA's Steve Bowen to discuss the situation. CAPT Wilkins set up two "Tiger" teams to try to solve the problem of target discrimination. The first team focused on software and data analysis in an attempt to manipulate the incoming information to improve target identification. The second team focused on hardware testing. Doug Lockhart was tasked as the Testing Director. Mr. Lockhart planned a series of tests on the 8101, 8125, Klein 3000, EdgeTech MPX, Marine Sonic (standard configuration), and the Marine Sonic (custom 10-degree down angle). Testing required the location of two suitable control areas 100 x 200 meters in 20 feet of water and in 75 feet of water. An area was selected and thoroughly scanned with both side scan and multibeam to map the existing bottom conditions. Upon completion of the initial scan, 10 targets were placed 10 meters apart on a 100-meter long track. Included in these targets were three OEX Data

Figure 3-15. Sample Targets used for Controlled Test.

Recorder mock-ups provided by NASA. Sonar reflectors were placed at the beginning and end of the test track to provide sonar analysts an unmistakable target area. Figure 3-15 contains a picture of a number of these targets.

The multibeam and side scan systems were run directly over the targets and out in 10-meter scan lines. As with the initial survey scan, the test scans were run both perpendicular and parallel to the targets. Testing was conducted in the shallow and the deep water sites on March 15 and 16. Appendix G is a comprehensive test report that lists the systems tested and the test results. The result of this testing was the selection of Reson 8125 multibeam, Klein 3000 side scan, and a custom tuned, 10-degree, Marine Sonic 600 kHz. This equipment was proven to be best configured to find shuttle debris. The remaining search assets were demobilized since they were proven to be less effective for the selected targets in this environment.

3.4.3 Consultation

In addition to the expert consultants brought to the scene on March 11 and 12 to support the search asset testing program and multibeam data processing analysis, SUPSALV invited a second group of industry experts to Toledo Bend Reservoir to review the search process as it had been refined based on the formalized system testing. SUPSALV wanted an independent review of the established process to confirm that the solutions in use were the best available given the unique environmental conditions and target characteristics. On March 21 representatives from Scripps Institution of Oceanography, Woods Hole Oceanographic Institute (WHOI), National Oceanic & Atmospheric Administration (NOAA), and Office of Naval Research (ONR) were briefed on the search operation. The results of the formalized testing and subsequent selection of preferred assets were reviewed. Consideration was also given to a number of other potential search assets. They are listed below along with some discussion on their ability to support the operation.

Laser Line Scan - A powerful search tool but the cluttered lake environment, the tow fish's large size, poor visibility within the lakes, and relatively high lease costs were negative factors contributing to its non-selection.

Magnetometer - Considered but the majority of the space shuttle debris was non-magnetic and would not be detectable with this system.

Synthetic Aperture Sonar - Sends out simultaneous, multi-frequency emissions of sound through the water. Manufactured by Applied Research Laboratory at Penn State University. Provides very high resolution with shadow nullification at very high range. There were several problems noted with this system. They included: the equipment is not widely available, it is expensive, it is very large in size, and it requires a number of technicians to run it. As with all the considered systems the problem of target discrimination was unresolved.

GeoPhex - This is a towed metal detector. It was considered late in the operation, since it might be useful in the shallow water where the thick marine plant life precluded use of a below-the-water system. Conversations with the manufacturer indicated that the detection range was 5 to 10 feet when towed on the surface, therefore the area that could be effectively covered in the time remaining would be limited.

EdgeTec MPX 455 KHz - Tested in the March 15 and 16 controlled testing but the backscatter and noise in the imagery made detection of test targets more difficult than with the other systems tested. The physical size of this unit would make handling the system from the small boats difficult, and at the time, there was only a single unit in existence.

Echotrack Low Frequency Echosounder - Tested in the Toledo Bend Reservoir on March 15. The Echotrack was mounted on a bow-mounted rigid pole. After running the system through the test range at 24KHz it was very difficult to see the test targets and distinguish them from trees and ground clutter. Other drawbacks are the data output is in paper form only and because only a single beam is transmitted, the effective coverage per pass is reduced.

Klein 5000 - This is a high-resolution side scan system but it requires towing at high speeds to achieve high resolution. Given the boats available and environmental conditions on the lake, operators would be forced to work slowly, not allowing the additional beams to be employed. Resolution at slow speeds would be the same as the Klein 3000.

After reviewing the current search assets and procedures, the consultants did not have any suggestions on what could be done to improve the odds of finding shuttle debris. They confirmed that the SUPSALV led teams were employing the best solutions possible given the existing conditions.

3.5 Diving and Recovery Efforts

3.5.1 Coordination of Dive Teams

Diving operations were conducted by a wide variety of organizations and were a vital component of the overall operation. The diving and recovery efforts evolved substantially from the first days after the accident to the final days of the operation. The Navy dive management team provided a strong organized approach that resulted in more than 51 days of diving without incident. This process also ensured that the search for shuttle debris was comprehensive. Initially, the dive teams were managed from the Fairmont Volunteer Fire Station. FEMA and EPA arranged to have a helicopter pad constructed to aid in the removal of a potentially injured diver, a microwave radio tower was brought in, and radio communications were established at the fire station. On February 26, the base of operations moved to the Fin and Feather Resort on the bank of Toledo Bend Reservoir where the Dive Team were co-located with the Search and Analysis teams. The Fin and Feather was also the home of the MDSU TWO recompression chamber and air compressors.

In order to ensure diving operations were conducted efficiently, an orderly process was needed and daily management of that process was required to ensure safe and effective results. SUPSALV and MDSU TWO senior staff managed the teams by assembling them each morning for a dive brief. During this brief, the dive team supervisors, buoy drop boat operators, and security boat crews received their assignments for the day. Additional information, such as forecasted weather conditions, expected fishing boat activity, and new information from NASA was conveyed. Figure 3-16 is an image of the diving leadership assembled for a morning dive brief and Figure 3-17 is a representative snapshot of the diving, buoy drop, and security team assignments.

Figure 3-16. Daily Dive Brief.

In order to put the dive teams on the targets, a comprehensive dive package was needed. In coordination with the search team management, the dive package concept was developed. To prepare these dive packages, the search management team, working the night shift, selected 12 – 20 target sets. Extra dive area packages were developed so the dive management team could shift the dives if weather conditions at the primary sites proved unfavorable. At the dive brief, the primary and backup dive packages were provided to each of the dive supervisors. The package consisted of:

1) Three charts of different scale identifying the location of the dive area.

2) Target identification list, including target ID, target latitude and longitude, grid center latitude and longitude, and a target description.

3) Details of each target, including the Sector and Grid ID as well as the sidescan image of the target.

Activity	Organization	Call Sign	Boats	Persons on Vessel	Area of Operation
Dive Team	Houston Dive Team	Houston DT	2	8	Area W
	Galveston Dive Team	Galveston DT	1	4	Area X
	Texas Department of Public Safety	DPS	2	11	Area A
	Environmental Protection Agency	EPA 1	1	4	Area 1
	Environmental Protection Agency	EPA 2	1	8	Area 2
	Navy	Navy1	1	6	Area 6
	Navy	Navy2	1	7	Area 5
	Navy	Navy3	1	6	Area 3
Buoy Boat	Louisiana Parks and Wildlife	LA2	1	4	Area W
	Texas Parks and Wildlife	TX2	1	2	6 Mile
	Texas Parks and Wildlife	TX1	1	2	Finger 3 (Dive area 2 & 4)
Search Teams	C&C	CC1	1	4	6 mile
	C&C	CC2	1	2	Horseshoe Pt
	SUPSALV	SUPSALV1	1	3	Paradise Point
	EPA (Innerspace)	EPA Sonor	1	4	6 mile
	Phoenix	PHX	1		Lake Nacogdoches
Security Boats	Louisiana Parks and Wildlife	LA1	1	2	6 mile
	Coast Guard	CG02	1	2	6 mile
	Sabine River Authority	SRA1	1	2	Paradise Point
	Sabine River Authority	SRA2			Stand by
	Jasper Police	Jasper	1	2	Paradise Point
Total			**22**	**83**	

Figure 3-17. February 27 Dive, Search, and Security Assignments.

Appendix H is a representative example of dive package components. The large scale chart has a grid overlay. Grids were applied to the entire search area at a spacing of 30-meters.

At the beginning of the operation, initial sonar searches resulted in selection of nearly every item on the bottom as a target. The dive teams had to dive on hundreds of tree stumps that were identified as targets. Figure 3-18 is a subset of the Toledo Bend target plot showing two creeks where targets were selected indiscriminately.

The ability of the sonar analysts to discriminate between stumps and more valid targets was fostered through a feedback process. The divers annotated the results of the

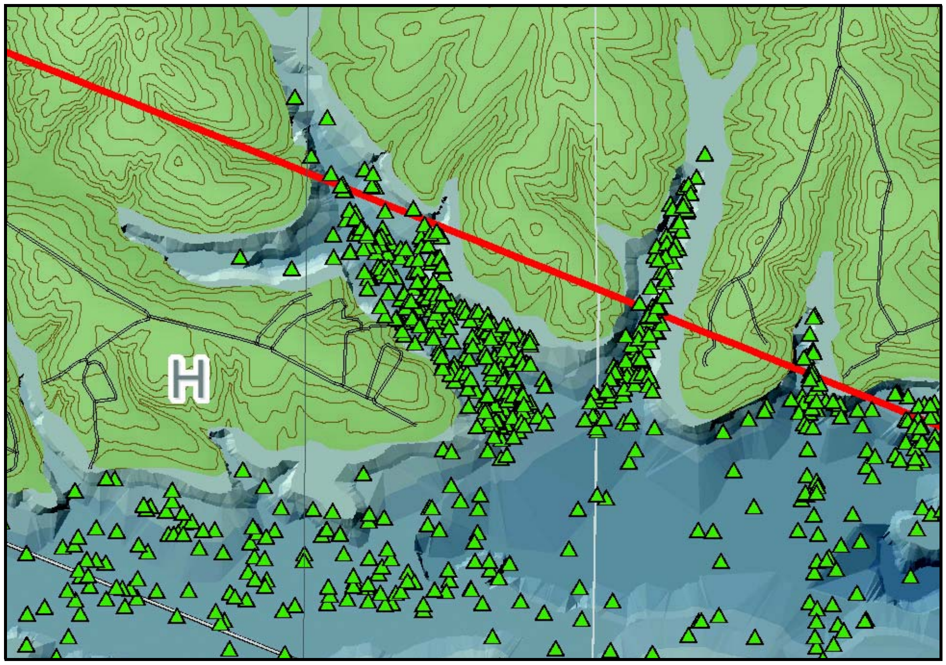


Figure 3-18. Toledo Bend Reservoir Targets in Western Finger Creeks.

dive on the Daily Team Target Assignment and Roster that included the image of the target. These annotations were returned to the sonar analyst at the end of the day. The analyst not only updated the target database indicating that the target was cleared, but also reviewed the findings and compared them with the sonar return image. This allowed the analyst to become familiar with the size and shape of the items as the divers identified them. This feedback process greatly reduced the number of tree stump targets and increased the likelihood that the analyst would select man-made targets.

3.5.2 Debris Recovery Plan

One of the earliest problems encountered in the water recovery operations on Toledo Bend Reservoir was the preponderance of man-made objects on the lake floor. Since the reservoir was once a dry, inhabited area, it is cluttered with remnants of the former residents. There are railroad tracks, barns, mailboxes, churches, cemeteries, cars, trucks, old boat docks, bridges, trailers, construction equipment, and more littering the lake floor. After the reservoir was flooded and became a major fishing and recreation area, more man-made debris was added. In addition to the original clutter, the bottom is littered with beverage cans, bass boats, fishing tackle, boat motors, tires, refrigerators, wheel rims, hubcaps, aluminum siding, boat and car batteries, and boat anchors.

EPA, in conjunction with NASA, established guidelines for the collection of space shuttle debris from the ground. The guidelines were provided to personnel involved with the search in order to give them an awareness of the potential hazards associated with some of the material, recognize significant hardware, and provide procedures for dealing with the unique types of debris recovered. Shuttle debris was divided into four types:

1. **Crew Related Material** – Searchers were not to attempt to recover this material. They were told to notify the EPA/START (Superfund Technical Assessment & Response Team Contracts) Team Leader, who would obtain the GPS fix and notify the FBI immediately.

2. **Hazardous Material** – If searchers recover/discover this type of material or suspect hazards exist, they should not attempt to recover or investigate it. They should secure the area and notify the EPA/START Team Leader. Specially trained personnel were dispatched to recover the items in priority order. Potential hazards included:

   - Stored Energy – Tanks, cylinders, landing gear, tires
   - Monomethyl Hydrazine – Clear liquids in tanks
   - Nitrogen Tetroxide – Greenish liquid or brownish vapor
   - Ammonia – Clear liquid stored in tanks
   - Pyrotechnic Devices – Landing gear, window frames, crew seats, hatches, antennae
   - Biological Material

3. **Significant Material** – These are items that may provide information critical to the investigation. Significant material included “black boxes”, electronic circuit boards, cameras, magnetic tape, large structural or wing components.

4. **All Other Material** – The search team should bag the item and notify the EPA/ START Team Representative. The EPA/START Team should record the location and photograph the item before transporting it to the nearest collection station.

For the water search organization, the plan for items found in the water was to document the location of each item via GPS and place material in a plastic bag. Electronics were to be kept submerged until the EPA/Start Team arrived. U.S. Air Force Explosive Ordnance Disposal (EOD) Unit briefed Navy officials on what hazardous materials were present on Space Shuttle Columbia. They provided descriptions of various targets so divers would be able to identify them. If these items were encountered, divers were instructed to mark the target and leave it in the water for an EOD team or EPA START Team. One example was the front landing gear (nose gear), which contains a pyrotechnic part that activates in case of hydraulic failure. When the front landing gear was located, the pyrotechnic piece was missing and was possibly on the bottom of Toledo Bend Reservoir. Every new dive team that arrived on the scene was briefed on how to handle these targets if encountered.

3.5.3 Techniques and Assets

While neither Lake Nacogdoches or Toledo Bend Reservior was deep enough to require the use of non-SCUBA systems, the dense tree coverage on the bottom of the Toledo Bend Reservoir required extra planning and attention to detail in preparing dive operations. In water less than 60 feet, SCUBA was the preferred method for diving. Due to the higher risk of diver entanglement, the decision was made to restrict dives greater than 60 feet in heavily forested areas to surface supplied diving. It was felt that the quantity of air available took much of the risk out of the deeper dives and was worth the encumbrance that managing the umbilical entailed. This section describes the three diving methods practiced on the lakes and ponds of East Texas.

3.5.3.1 Pond Diving

People reported sightings or sounds of debris hitting the water throughout the ponds of East Texas. NASA collected this information but as it was not visible and easily retrieved, many of the leads were not pursued. When the water search operation was fully staffed, NASA delivered a rough list of contacts who had reported debris falling in the water.

NAVSEA and MDSU TWO formed a team to call each of these contacts, set up an interview to obtain as much information as possible about the suspected sighting, and determine if a compelling reason existed to send a dive team to the site to attempt to locate the debris.

Many of these reports led to shallow bodies of water on farms in rural parts of the state. When a report was considered valid, a team of two or three divers attempted to locate the debris. These were often snorkel dives or accomplished by wading into shallow waters to conduct the search. These pond divers were successful in recovering shuttle debris from some of these searches. Figure 3–19 is a photograph of a pond diver and Figure 3-20 is a sample page from a log used to track and document results of each of the reports of water debris (the contact names and addresses have been removed for this display).

Figure 3-19. Pond Diving in an East Texas Lake.

3.5.3.2 SCUBA

Nearly ninety percent of the diving operations carried out on Toledo Bend Reservoir and Lake Nacogdoches were SCUBA dives. The Navy assigned targets to SCUBA teams when the depth was generally less than 60 feet and the density of the trees was not restrictive. SCUBA operations were carried out by up to four teams of MDSU TWO divers, and Galveston and Houston Police Department dive teams. EPA and Texas DPS dive teams used surface supplied diving systems. Individual non-U.S. Navy dive teams dove to their own agency rules and regulations. Searching procedures were established by utilizing the experience of all teams and coming up with methods that would best fit the challenging conditions of Toledo Bend. SCUBA divers utilized both single and double tank rigs with MK 20 AGA masks equipped with OTS Aquacom through water communication systems. The dives were challenging as the selected targets were generally small in size and the trees, stumps, and debris on the bottom were a distraction. The loose sediment that made up the lake bottom was easily disturbed by diver action. When this happened, visibility quickly deteriorated from the normal 1 to 3 feet to a few inches.

A typical SCUBA dive operation was carried out in the following manner. First, a drop buoy was set as close to the position provided in the dive package as possible. EPA and Texas DPS used drop boats manned by Louisiana Parks and Wildlife and Texas

ID	REPORT SHEET	CALL BACK NUMBER	LAST CALLED	STATUS	CITY	STATE	LAT	LONG	DEBRIS DESCRIPTION COMMENTS
24343		(903) 432-2343	5 Mar	Closed	**Dallas**	TX			3-4' piece is half embedded in the water. Town is SE of Dallas. Terrain is very rough. Take 175 to 274 into Seven Points to stop light. Take right on Hwy 85 west to Ennis. Take left on 1st Road (blacktop) about 1 mile. Item turned out to be a vehicle hood.
	Yes	(409) 565-4667	1 Mar	Closed		TX			Piece landed between docks with a big splash. Conducted LIMIS, handheld sonar and visual search of area, nothing found.
	Yes	(409) 384-8046 (409) 383-0220	4 Mar	Closed	Broaddus	TX			55 Gallon drum size piece of debris. Located by Hwy 147 bridge. Witness heard fisherman talking about large piece of debris that hit south of Hwy 147 bridge in Sam Rayburn Reservoir. He did not see the object hit or know even a general location. Information is second person heresay. He did not know witnesses names. Witnesses claim a 100 foot splash they saw from a mile away.
2567		(214) 789-8383	4 Mar	Closed					Large debris. Cell (713) 882-0554. Item was on land and recovered by sheriff.
14839	Yes	(409) 579-4216	4 Mar	Closed	Hemphill	TX	31-17-15	93-46-28	Saw large silver object fall across his home to the west. Did not see anything land on land or in the water. Item flew over his house west(?). Witness was sure it was west. Conducted limited search of area, saw no debris.
22974		(409) 789-6607	4 Mar	Closed	Share Acres	TX			Saw some pieces hit Toledo Bend Reservoir. Phone number is not valid. He is not listed in the phone book.
	Yes	(409) 625-3564	4 Mar	Closed	Hemphill	TX	31-28-16	93-45-58	Saw 3 pieces spiraling down. One was as large as a person. Does not know where they landed. GPS coordinates are for his house. Flight path was 120 Magnetic. He believes object landed by Cypress Gulf Course.
	Yes	(409) 579-2882	4 Mar	Closed	Hemphill	TX			All phone numbers on list are not valid. He is not in phone book.

Figure 3-20. Interviews With Eyewitnesses Log

Parks and Wildlife to mark the target location with a buoy while the Navy and Police boats marked their own targets. This positioning was critical because the number of potential targets between the diver's location and the actual target would dramatically increase if the diver was deployed off-target.

A number of devices were employed to aid the diver in directing his search in this restricted visibility environment. The first aid included use of a sector scanning sonar, which was lowered to the bottom before the diver deployed. This sonar gave the dive supervisor a chance to review conditions in that grid (the 90 ft. by 90 ft. squares that the lake was divided into) and if possible, reacquire the image of the selected target. Once the diver was on the bottom, he would be vectored in using the sector scanning sonar and through-water communications to the selected target.

Two additional aids used by a number of the dive teams included the AN/PQS-2A handheld sonar (all Navy teams) and the Garrett Sea Hunter metal detector (Houston Police Department). Once the selected target was inspected, the team would employ the diver-held equipment and the surface monitored sector scanning sonar to sweep the surrounding area to ensure the grid they were operating in was cleared of any other possible shuttle debris. The divers investigated all possible targets if additional investigation was warranted before exiting the water and moving to the next dive site.

3.5.3.3 Surface Supplied Diving

MDSU TWO arrived on scene with two Light Weight Dive Systems (LWDS). It was thought that surface supplied diving capability would be valuable in deep water and if the divers were required to do substantial work on the bottom. In addition EPA and Texas DPS used surface supply diving rig routinely. In Toledo Bend, the LWDS was used when dive depths exceeded 60 feet and the bottom was cluttered with a large number of trees. The system gave the diver time to work around the debris on the bottom and resolve any fouled umbilicals that occurred during the dive. Initially the Navy's surface supplied equipment was set up on a flat bottom 24-foot boat but this boat did not have enough deck and cabin space for the divers. LWDS equipment was later moved to a Coast Guard 32-foot boat which was a much better fit for the job. In both cases, anchoring in water where depths approached 100 feet was difficult.

If a large piece of debris had been encountered, surface supplied divers would rig the debris for recovery. Two barges equipped with cranes were identified on the lake and one of them would have been used to perform the lift.

3.5.3.4 Grid Search

At the request of NASA Astronaut Jim Reilly, SUPSALV agreed to begin limited grid searches in Toledo Bend Reservoir along the NASA flight line. The two criteria for choosing a grid site were:

- Eyewitness reports of debris falling in the water
- Radar tracks showing debris falling and disappearing over the reservoir area.

To perform a grid search, SCUBA divers set up a 90 ft. by 90 ft. box and began running lines inside the grids. As an aid to searching for debris, the diver used a Garrett Sea Hunter XL 500 pulse induction underwater metal detector. The grid was searched in 5 ft. by 45 ft. segments in the more open areas. Some extremely cluttered areas called for a wagon wheel search method using several center points in a grid. Figure 3-21 shows the typical pattern used to complete a single grid.

Grid searches were utilized on a not to interfere basis with diving on targets. As teams were available, grids meeting the priorities identified above were assigned to dive teams. A total of 88 grids were searched in the last days of the operation. This covered approximately five and one half acres. As the significant debris density in this area was expected to be one significant piece per 500 acres (NASA estimate) and a single grid search in water less than 40 feet deep took about 2 hours, it would take about 17,000 hours of bottom time to search enough lake bed to find that one significant piece of debris. After the 88 grids were searched, a single piece, approximately one inch in diameter, was found. It was listed as a probable shuttle piece. Other items found included: nails, railroad spikes, and hundreds of beverage cans.

3.5.4 Supporting Dive Gear

In addition to the basic SCUBA gear each diver wore, the Diving Operations team was interested in outfitting the divers with anything that would improve the probability of success on each dive. Options considered are listed in the following sections.

3.5.4.1 Sector Scanning Sonar

A very successful addition to the dive team suite of gear was the Kongsberg Simrad Mesotech LTD MS 1000 sector scan sonar. The first unit was offered to the Houston Police Department dive team. Their appreciation for it in these low visibility waters generated interest by the Navy dive teams. The Houston, Texas representative for this

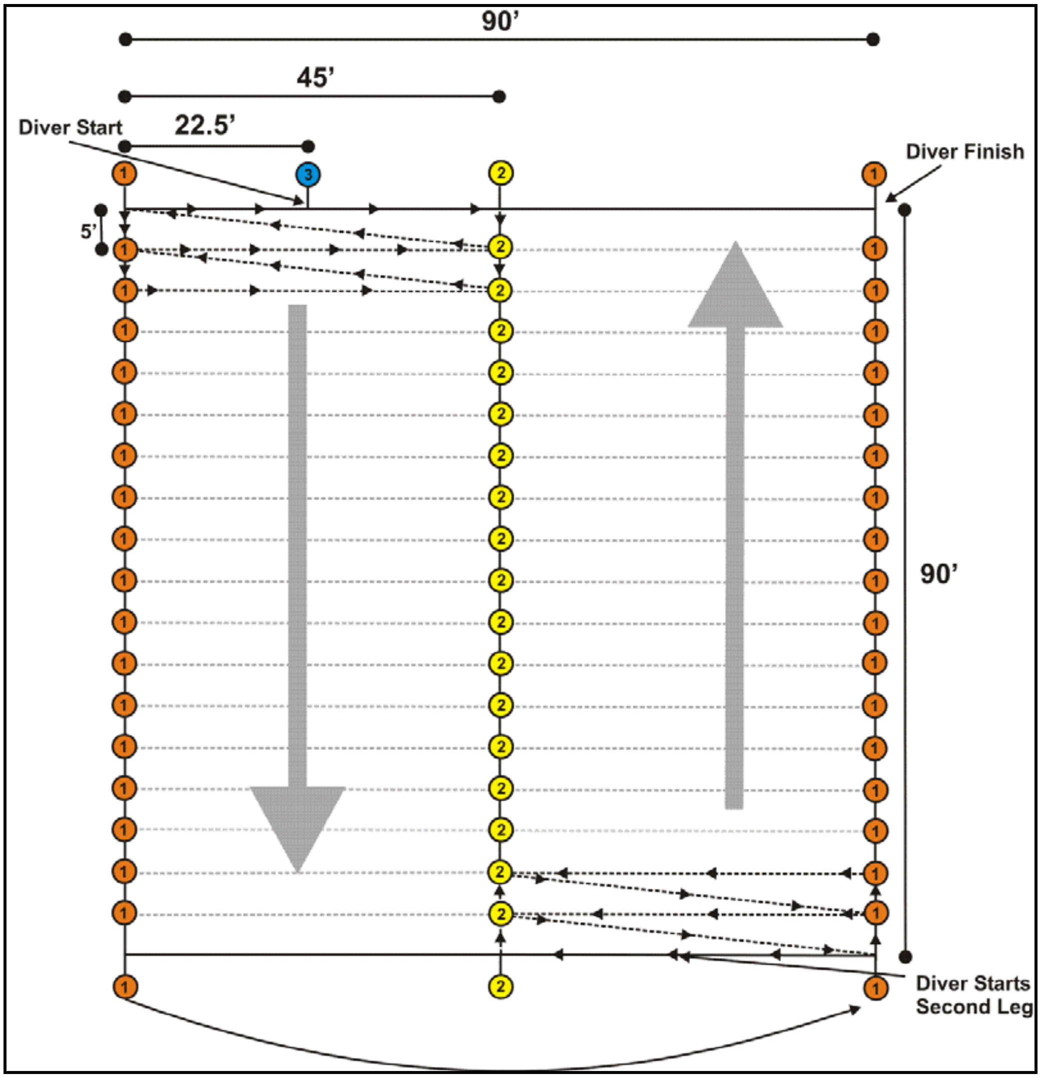


Figure 3-21. Pattern Used to Complete a Single Grid.

Canadian gear was able to provide four additional sector scan sonars and two manufacturer's representatives provided training for dive teams. Four additional units were later leased so each dive team was equipped with one of these sonars. These sonar systems were hung on a tripod mounting system and were dropped to the lakebed in the center of each search sector. The sonar's imagery was transferred to a laptop on the surface. Due to the density of stumps and trees at depth and the need for image clarity, the laptops were ordered with high-resolution monitors. Search scan ranges were limited to 30 meters to achieve maximum resolution and clarity. A sonar operator on the surface vectored the diver to the target through his in-water communications system. While the sonar was deployed, the dive teams cleared any probable additional targets visible using the sector sonar. Figure 3-22 is a diagram showing how the sector scan sonar was used on a target field. Figure 3-23 is an example of the screen image displayed on the surface laptop screen. This screen paints a number of items on the bottom and the diver operating on the bottom.

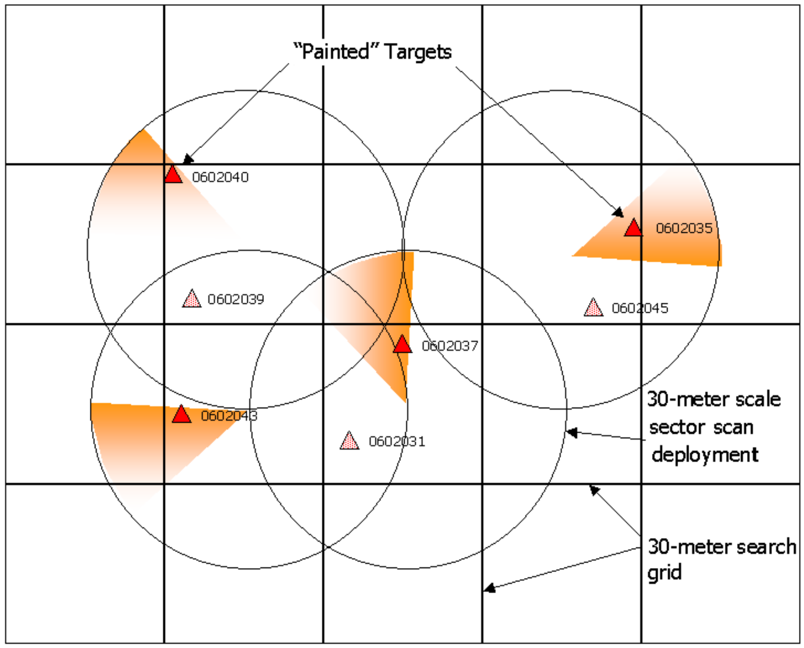


Figure 3-22. Deployment of Sector Scan.

3.5.4.2 Through Water Communications

The dive teams employed the Aquacom SSB-2010 Transceiver through-water communications system. In any normal search/salvage operation communications between the divers and topside are important. The extreme lack of visibility at depth in Toledo Bend Reservoir made communication between the divers and topside absolutely critical. With the Aquacom through-water communications system the divers were guided to the targets by the topside operator of the sector scanning sonar. In that near zero-visibility environment, the vectoring information provided by the dive supervisor topside was necessary if the divers were to reach and inspect the targets identified by the sonar analyst. It was also critical because it provided the divers with the ability to report conditions, entanglements, and observations to the topside watch.

3.5.4.3 AN/PQS-2A

MDSU TWO divers brought the AN/PQS-2A hand held sonar to East Texas. These units identified targets with an audio signal transmitted to a headset worn by the

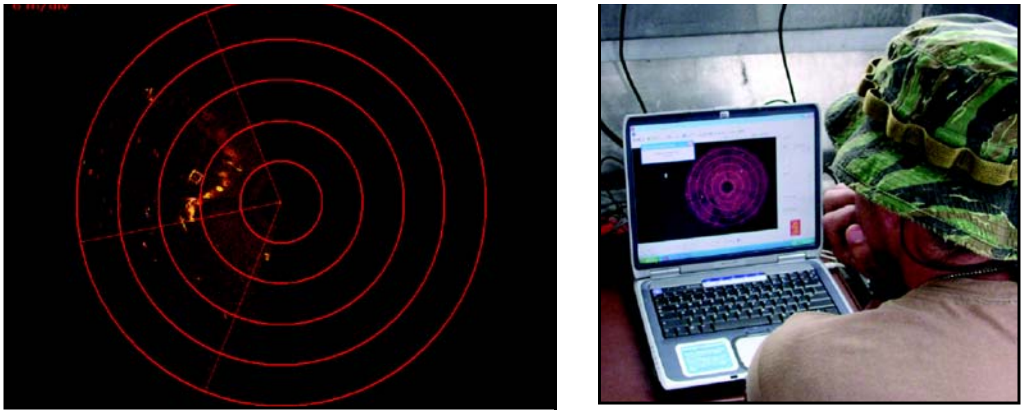


Figure 3-23. Sector Scan Screen Display.

diver. In much the same way as the Houston Police Department Dive Team, the MDSU TWO divers dropped down to the center of the target area and conducted a 360-degree sweep looking for targets.

3.5.4.4 Limpet Mine Imaging Sonar (LIMIS)

LIMIS is a hand-held underwater sonar that transmits data via visual display directly to the diver through a diver-worn, heads up display attachment to the MK20 helmet or SCUBA mask. Currently, there are only two LIMIS systems in existence. The Coastal Systems Station (CSS) is currently testing LIMIS for Explosive Ordnance Disposal (EOD) teams. LIMIS is based on new imaging technology called Dual frequency IDentification SONar (DIDSON). DIDSON is a high-definition imaging sonar designed and manufactured by the University of Washington's Applied Physics Lab for military applications such as diver detection and underwater mine identification. DIDSON operates at two frequencies: 1.8 MHz for close range observations less than 12 meters and 1.0 MHz for detecting targets at ranges up to 30 meters. At closer ranges, DIDSON provides near-video quality images. Its primary function is to scan the smooth hull surface of ships during harbor security dives. LIMIS works on the same principle as side scan sonar. Objects scanned stand out as sonar images. As the distance from the target grows, the signal resolution is drastically reduced. This diminished resolution at-range would have been a significant factor increasing the time required to clear a dive site if LIMIS was used in the debris dense Toledo Bend Reservoir environment.

The LIMIS system was brought in as a possible enhancement to the imaging capabilities that the Kongsberg Sector Scan sonar system provided the dive teams. Drawbacks to LIMIS are the amount of time it takes for diver to get familiar with analyzing the sonar return and the comfort level associated with operating a heads up display unit, such as loss of perception and ability to see peripheral targets. Given the time it would take for each diver to become comfortable with the system and the conditions in the lake (substantial amount of ground clutter, the contours of the lakebed, and the expected small size of shuttle debris), it was determined that the LIMIS system was best reserved for small areas and local searches (ponds, etc.).

3.5.4.5 Metal Detectors

Near the close of the operation NASA asked the Water Search team to provide a detailed search of a few specific areas based on eyewitness sightings or assumed positions based on debris found on land. This was done using a grid search technique outlined in Section 3.6.4. The grid search effort was augmented with Garrett Sea Hunter metal detectors. Visibility in the water was very poor, particularly after a diver had stirred up the silt through bottom contact. Given those conditions, metal detectors gave the divers another tool for searching for debris. Eight Sea Hunter metal detectors were delivered to Toledo Bend on 17 March and were used by all of the dive teams during the final weeks of the operation. The metal detectors were very effective in locating small objects on the reservoir bottom. When the diver passed the detector wand over a buried metallic object, a signal was transmitted to the diver via headphones. The audible nature of the signal provided clues to the size and distance of the object. These metal detectors were used both on grid searches and in the prosecution of the sonar-identified targets. The fact that these units responded to all metallic objects caused divers to investigate many non-shuttle items such as aluminum can pull tabs and nails.

3.6 Demobilization

Search operations were completed on April 11. The last diving day was April 12, 2003. Individual dive teams packed up their dive gear and boats and were released. For MDSU TWO, this included several large equipment vans, the dive compressors, and the TRCS which rides on a tractor trailer. Phoenix had a more complicated job to close up the operation. For one, NASA had asked that the data generated on the operation be made available for possible review or post-processing. To accomplish this, Phoenix procured two remote hard drives (RAIDS) and copied all the search data and databases onto these two disks. The data consisted of approximately 2 terabytes of information.

Material procured for this operation also needed to be accounted for. As FEMA funded the operation, they asked that items of significance be inventoried and returned to them. Phoenix had anticipated this and arranged for accounting staff to help document the inventory and pack the equipment for FEMA pickup. The remainder of the material was brought to the site by Phoenix and belonged to the Navy. This material was packed and shipped to Phoenix's warehouse in Landover, MD.

Section 4

Challenges

and

Lessons Learned

Section 4

Challenges and Lessons Learned

4.1 Challenges

The Navy's task of recovering significant Columbia Space Shuttle debris from the lakes of East Texas was challenging for a number of reasons. The combination of the small size of primary high interest targets and the heavily forested lake floor provided one of, if not the most challenging searches ever undertaken by SUPSALV. This section identifies the challenges the team faced and the methods they used to resolve them.

4.1.1 Nature of Debris

The Space Shuttle Columbia was re-entering the Earth's atmosphere in an east southeast direction when it broke up. Debris was scattered from the Dallas – Ft. Worth area to western Louisiana. Due to the extreme speed of the shuttle, it broke into very small pieces. As of May 5, over 82,000 individual pieces of debris had been recovered representing about 38 percent of the shuttle. The recovered pieces are small and weigh an average of one pound. So far, the largest piece recovered is only 6 ft. x 8 ft.

In late February, NASA had reached some conclusions about the pattern of the debris field based on the material that had been recovered. They described the debris field as one that consisted of generally less dense material having landed first, in the northwest, and the greater density material landing last, in the southeast. This was graphically demonstrated by the fact that the very dense engines traveled all the way to Louisiana. Based on the analysis of the debris pattern, it was considered likely that some of the shuttle avionics bays may have landed in the Toledo Bend area.

NASA identified the items of high interest that could provide the clues they needed to determine the cause of the accident. NASA's decision was to focus on the OEX Data Recorder, which measures approximately 7.5 in. x 17 in. x 22 in. NASA hoped that if the OEX Data Recorder was recovered, it would show the last 25 seconds of flight data before the shuttle was lost.

The moderate size of the OEX Data Recorder was at the extreme lower end of the targets SUPSALV's search systems were able to discriminate. In fact, the OEX Recorder was recovered by a ground search team from a woods about 8 miles West of Toledo Bend Reservoir on March 20. The recorder was found intact and contained the data from the last seconds of the flight. Figure 4-1 is an image of the OEX Recorder.

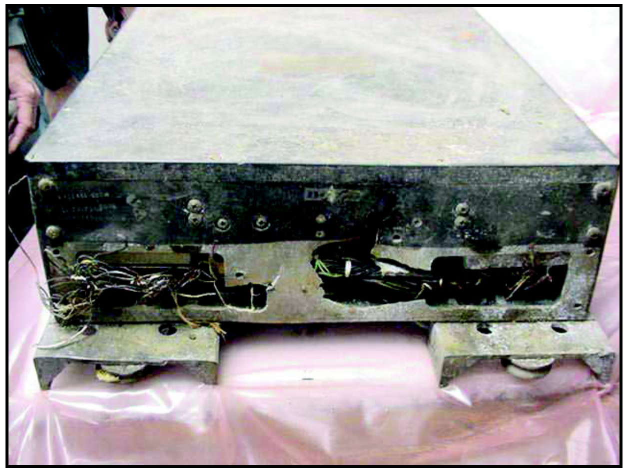


Figure 4-1. OEX Recorder, Recovered March 20 in Woods East of Hemphill, TX.

Following the OEX Recorder other items of interest included: left side wing components, instrumentation, other data recorders, and electronic boxes. These electronic items were described to be small, roughly 18 in. x 24 in. Other items of less significance included aluminum alloy skin with bonded stringers, tiles attached to the skin, and various stainless steel and titanium tanks. These tanks may have contained dangerous materials and the divers had been instructed to let the U.S. Air Force EOD recover these items if found.

4.1.2 Lake Conditions and Terrain

The Toledo Bend Reservoir was a hostile environment. The combination of natural and man-made material cluttering the lake floor and the number of standing trees in the water column made this a most challenging search.

After the Toledo Bend Reservoir dam was finshed, it was anticipated that the reservoir would require three years to fill, but a series of 100-year storms in 1967 filled the reservoir in just three months. As a result, the planned harvesting of the forests did not occur and much of the reservoir bottom closely resembles the forested valleys that surround the reservoir. Tree stumps and whole trees extending above the surface cover the reservoir and limit free travel across the lake surface. These trees also provided a

Figure 4-2. Trees on Toledo Bend Reservoir Surface.

dangerous environment for divers, entangled towed devices, and seriously compromised the sonar search process. The challenge to the search process resulted from the extreme number of contacts for the analysts to sort through and inability to “see through” to the lake floor as the sonar return was shadowed by standing trees. Figure 4-2 is a typical image of trees extending above the surface of Toledo Bend Reservoir.

Much of the surrounding countryside was swampy lowlands with dense forest growth. These areas had limited access and not enough depth to support the use of commercial type search and dive boats. As a result, the dive teams waded into the ponds when checking valid reports and the NASA teams searched these areas with waders with poles.

The tree-filled lake caused extreme wear and tear on the towed and hull-mounted sonar equipment. Most of the time, the side scan sonars were towed at a depth of five to six feet. These sonars, also called “fish”, were routinely bouncing off trees. Often the fins became broken or bent and a number of electrical connections, called “pigtails”, broke or suffered electronic failure.

The Reson multibeam sonar was also vulnerable as it projected below the waterline and was hard-mounted on the bow. Direct impact with submerged stumps completely stopped the boat and occasionally damaged the "cow catcher" on the front of the beam. Many of these incidents broke the shear pin holding the multibeam rail in the vertical position. During the first three weeks of operations, the operators ran through their entire stock of shear pins. Until the supply of replacement threaded fiberglass rod shear pin stock arrived, the operators used ¾-inch dowels to hold the beams in position. During a single week, they ran through 40 feet of this dowel rod stock in 4-inch increments.

Given the nature of the "standing" debris on the lake bed, the water search teams were fortunate that the operation occurred during the winter months when the water level was on the rise. At the start of the operation, the water level was near normal but within days, the steady spring rains raised the level to the +3 to +4 foot range. This level was maintained through February and into March. During the second half of March, after a period of dry weather, the water level began to drop. SUPSALV contacted the Sabine River Authority and requested that the level be maintained as high as possible to facilitate searches outside the marked channels. The river authority complied and restricted the flow out of the dam in order to maintain the favorable water levels.

4.1.3 Logistics

The rural nature of the area surrounding the Toledo Bend Reservoir provided a substantial logistical challenge. Houston and the Gulf Coast were three to four hours away and local suppliers were not always able to fulfill the specialized requirements of this operation. This often resulted in a full day delay in obtaining supplies or material.

4.1.4 Work Boats

One of the major components needed to make this operation successful was suitable work boats. Nearly all of the suitable work boats from South Texas and the Gulf Coast of Louisiana were leased in order to meet the requirement to survey and dive on the two lakes. EPA brought their own boats but most of the other dive teams and search crews operated from contracted vessels. The best boats for the job on this lake were aluminum-hulled, twin-engine boats with moderate sized cabins. By late February, SUPSALV accepted delivery of two single-engine boats since the stock of available twin-engine boats had been depleted.

4.1.5 A Base for Operations

The rural nature of the operation provided a major challenge in finding a base of operations for the search and diving organizations. On February 2, NASA and FEMA set up a temporary command post in the parking lot adjacent to the Indian Mounds boat ramp. This location had no communications assets and no shelter from the February weather. These shortcomings severely limited their ability to manage the operation. On February 8, NASA moved the diving command and control post to the Fairmount Fire Station. The permanent residents of that fire station graciously moved their trucks and equipment outside to provide space for the operation. FEMA arranged for phone lines to be brought in, constructed a helicopter pad to facilitate transport in the event of a diver injury, and arranged for a temporary cellular tower. Search direction and plotting were accomplished at the Six Mile Volunteer Fire Station that was configured similarly.

When the Navy arrived on February 10, one of the first tasks undertaken was finding adequate housing for both the MDSU detachment and the Phoenix search crews. After looking at a few of the small rooming houses in the area, they came upon the Fin and Feather Resort, a summer fishing camp, located on the southwestern shore of Toledo Bend Reservoir. The camp was largely shut down for the winter but was able to gear up and support the operation. The Fin and Feather initially supplied a limited number of accommodation cabins for divers, boat crews, and technicians and, after a few days, made a nearly finished meeting hall available to serve as an operations base and space for the plotting teams. Four phone lines and a satellite communications line were brought in and the plotting team moved from the Six Mile Fire Station to the Fin and Feather. The Fin and Feather had additional assets that made it a good base of operations. These included a large pier and launch ramp for the boats, plenty of parking lot space for boat maintenance and the MDSU TWO recompression chamber, and a restaurant. Eventually, a large capacity fuel tank was installed at the Fin and Feather pier to provide a local source for fuel for the search and dive boats. FEMA arranged for additional support including a T-1 communications line and security at the camp gate, the boat pier, and the operations center. The single point of land access to the camp simplified security measures.

On February 26, the dive management and communications crew moved from the Fairmount Fire Station to the Fin and Feather compound. This was done when construction of a large meeting room adjacent to the search team plotting spaces was

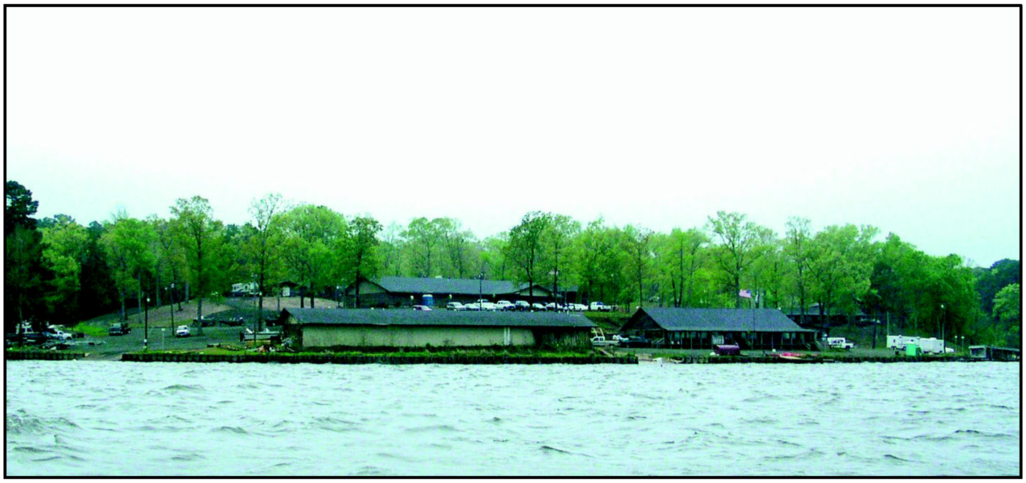


Figure 4-3. Fin and Feather Resort, Hemphill, TX.

completed. Eight phone lines and the radio communications suite were transferred from the fire station. The transfer of the diving operations function to the Fin and Feather greatly simplified communications issues associated with running the operation. The SUPSALV team considered themselves fortunate in finding a facility as large and flexible as the Fin and Feather. Operations would have been less than ideal without it. Figure 4-3 is a photo of the Fin and Feather from a returning dive boat.

4.1.6 Communications

The water search teams faced a major challenge in coordinating their efforts in the beginning of the operation. East Texas has very spotty cellular coverage and, with no base of operations, even conventional telephone communications were challenging. Over the first two weeks, FEMA responded by contracting a local carrier to install a mobile cellular tower at the Fairmount Fire Station and upgrade the phone service. The Texas Forest Service also contributed significantly by providing a radio base station, three sets of mobile radios (16 each), and a Texas Forest Service employee who manned the base station and maintained the portable radio sets. These radios, operating on a federal-only channel, provided reasonably secure and reliable means of communicating to all dive, search, escort, and buoy drop boats. This also permitted the MDSU medical staff to monitor the channel and be able to receive advance notice of incoming injuries. These communications systems, including the cellular tower, were transferred to the Fin and Feather Resort when the Diving Operations Center was relocated on February 26.

4.1.7 Equipment Maintenance and Re-supply

Due to the harsh nature of the underwater environment, many of the sonars suffered casualties over the course of the operation. Initially, in Toledo Bend Reservoir and Lake Nacogdoches, Marine Sonic sonars were used exclusively. The first failure occurred on February 23 and parts had to be ordered, as there were no spares available. A complete new towed sonar was ordered on February 25 from Marine Sonic to provide a backup capability.

On March 10, the Klein 3000, which had been working on Lake Nacogdoches, was redeployed to Toledo Bend. Within 45 minutes of beginning the Toledo Bend test course, the Klein collided with a submerged tree, parting the data cable. Repairs were possible on-site but took 12 hours. That same day, a Marine Sonics Centurion sonar hit a submerged tree and suffered extensive damage that rendered the fish unusable. SUPSALV replaced the damaged Centurion with the spare that had been ordered.

March 26 was another challenging day for the deployed assets. At that time, there were two Klein 3000 sonars on station but one had suffered a broken tow cable during the previous day's operations and was still being sought in the lake. The second Klein was receiving a new pigtail and one REMUS AUV was having its Long Base Line (LBL) replaced by the WHOI representative. These failures are examples of the equipment challenges the Columbia Water Search Team encountered during the operation. Figure 4-4 is an image of a Phoenix technician repairing a Klein 3000 sonar.

Figure 4-4. Klein 3000 Repairs in Progress.

FEDEX and UPS were constant partners in the operation as well as a number of suppliers who took the extra step in hand delivering the teams' orders. These vendors helped ensure the operation was successful.

4.1.8 Security

NASA was insistent that the media not have direct access to the search organization and that they should limit their contact to the public affairs staff in Lufkin. To control access to the public, local law enforcement were stationed at the Fin and Feather gate, the boat pier, and at the front entrance to the Command and Operations Center. The security teams also provided physical security for equipment and personnel. Access control was implemented through a badge system. Updated copies of the access list were given to the local police officers providing compound security. Only cleared individuals were allowed access to the compound and only badged individuals were allowed unescorted access into the Command Center. Physical security was also provided at Paradise Marina, where EPA and Coast Guard kept their boats, and at the Lake Nacogdoches boat ramp.

4.1.9 Interagency Coordination

As in any operation of this size and complexity, effective lines of communication were vital to achieve a coordinated and unified effort. The many organizations involved needed to form a cohesive unit to accomplish the challenging task. The Navy-led water search organization knew that effective communication was the key to coordinating its end of the search effort. More than 80 people were on the water on any single day and the shore support staff had to maintain communications, provide supplies, food, and fuel and oil for the boats. The shore organization also needed to designate search areas, identify diving targets, and coordinate emergency medical procedures.

It was also necessary to coordinate with and report to NASA, FEMA, and the EPA based in Lufkin, TX. The EPA was involved in this operation on a number of levels. They provided overall coordination through their Region 7 On-Scene Commander (OSC) umbrella, provided hazardous material recovery support using their REACT contractors, contracted with local ocean engineering corporations to provide search assets, and manned two boats with EPA divers. When the Navy was tasked to manage the water search, the EPA surrendered part of its “ownership” of the project and adapted to the Navy plan. After a short transition period, efficient joint operations were achieved and the capabilities of the EPA and Navy assets were effectively applied to the task.

NASA directed the search and on a number of occasions, the Navy adjusted their deployment to meet NASA’s changing requirements. One example was the list of eyewitness sightings NASA had collected during the first weeks after the accident. It wasn’t known how many of the sightings were credible but NASA and the Navy wanted to investigate each one as thoroughly as possible. To resolve this, NASA provided all details available about these reports and the Navy assigned a team who tracked down the phone numbers and names of the original reporting persons and conducted face-to-face interviews to determine if reports were credible and warranted further investigation. Positive interviews resulted in deployment of search assets to attempt to retrieve the reported debris.

On February 20, NASA reported details of progress from the land-based search. At that time, ten significant items (debris from the left side of orbiter) were found in the vicinity of Lake Bardswell. The Navy was notified that priorities might dictate deploying search assets to that lake. By March 4, interest in searching in Lake Barnwell had diminished to the point that deployment of assets to that lake was removed from the schedule. This is representative of the priority shifts that occurred during the course of the operation as NASA analyzed the debris recovered.

4.1.10 Weather

East Texas, along with the rest of the country, struggled with unusual weather patterns during the winter months of 2003. In the Toledo Bend area, search and dive teams encountered temperatures from below freezing up through the low 70’s. Strong winds during low pressure periods and winds that built over the day even in high-pressure systems prevented dive ops and sonar runs. Water temperature was 45 degrees which required use of wet or dry suits (diver preference).

Wind affected diving operations due to the Navy dive management team requirement to be able to return an injured diver from the dive site to the medical staff and recompression chamber at the Fin and Feather in 30 minutes or less. During periods of strong wind, high waves would prevent the dive boats from transiting from many dive sites on the eastern shore of the reservoir or the distant Paradise Bay creeks in that 30-minute time limit. Other factors affected by the weather include a boat's inability to hold its ground even after setting dual anchors. In winds greater than eight knots, the dive boats would drag anchor and prevent safe diving operations. The sector scans require the boats to stay in position while the sonar is on the bottom.

Running search lines with the side scan boats was also complicated by the high winds. High winds tend to blow a boat off its intended track. If the search pattern is disrupted the search becomes ineffective. Waves and high chop toss a boat vertically and rock it side to side. This impacts the scan by leaving a scallop type effect for the analyst to deal with. Waves also left air bubbles entrained in the water column which masked the return from the bottom. Figure 4-5 is a representative sample sonar image on a day where surface noise (wind and waves) affected the ability to conduct the bottom survey.

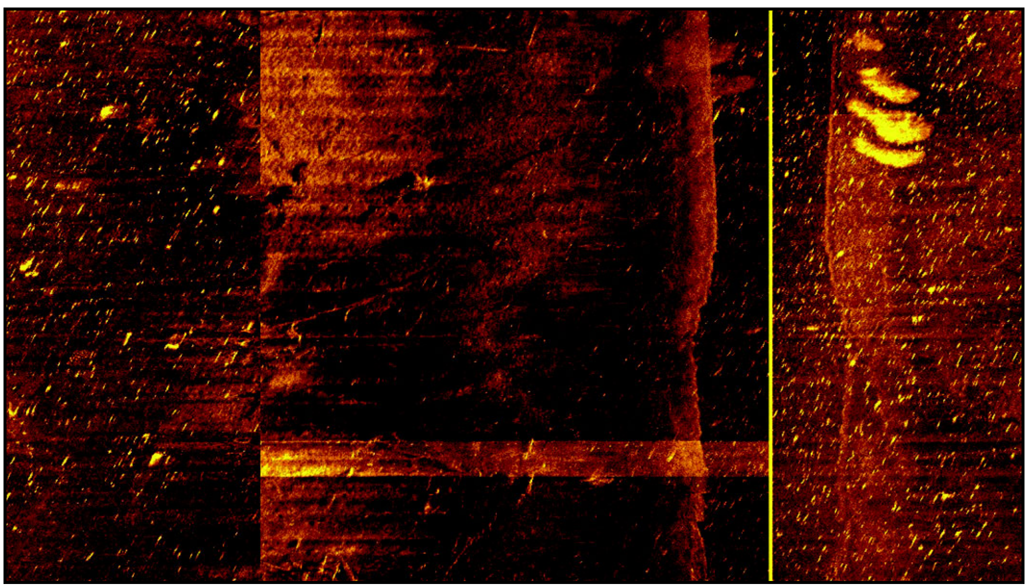


Figure 4-5. Example of Side Scan Sonar Imagery Degraded by Wind and Waves. Compare this to examples of clear imagery in Figures 3-6 and 3-11.

4.2 Lessons Learned

Over the course of the Columbia Search Operation, SUPSALV worked to improve the search and recovery process and attempted to resolve issues as they presented themselves. As a part of working out the best solutions, they came across answers that might have application outside the lakes of East Texas. Since SUPSALV is involved in major water search and recovery operations on a regular basis, it was deemed prudent to record these lessons in hope that they might prove useful on another occasion.

4.2.1 Ensure Timely Involvement

The Navy was tasked to support the operation on February 13 and arrived on the scene in-force on February 16. This was a full two weeks later than the other major agencies that began operations on February 1, 2, or 3. Even though SUPSALV contacted the Operations Center at the Pentagon on the day of the incident, the activities managing the project in Texas were not aware of the offer of assistance until SUPSALV contacted the DOMS in Lufkin directly on February 8. This delay resulted in the Navy starting search operations two weeks after the debris landed. The benefits of starting the operation earlier include anything from interviewing eyewitnesses while their recollections were still fresh to the possibility of getting to dive on the targets before silting became excessive (which the divers witnessed when leaving test debris in the water overnight).

Lesson: It is important to get the right resources involved at the very beginning of the recovery operation. If a water search is required, the timely involvement of SUPSALV resources should be a primary and initial consideration. SUPSALV contact information can be obtained through the web site at www.supsalv.org.

4.2.2 Clear Authority Simplified Control of Operation

The unambiguous tasking document issued by FEMA on February 10 directed the Navy to "…provide command and control of the underwater search and recovery effort as well as provision of additional U.S. Navy assets and personnel…". With this tasking, SUPSALV was able to control all the activities assembled on site including EPA, state, and local agencies. Without this clear authority, SUPSALV may have been challenged to impose the practices and procedures needed to run a disciplined operation.

Lesson: In any multi-agency operation, establish a clear line of authority.

4.2.3 Validate the Equipment and the Processes

After about three weeks of searching and not finding any shuttle debris, the water search team asked NASA for some actual shuttle debris to place on the lake floor to test their search processes. Tests were conducted on March 3 and 4 on four pieces of actual shuttle debris, irregular aluminum pieces ranging in size from the largest at 2 x 3 meters to the smallest at 0.3 x 0.7 meters. Figure 4-6 provides an image of this debris being placed in the test area by one of the Navy dive teams.

Figure 4-6. Actual Shuttle Debris Being Placed in the Water for Testing.

On March 3, each piece was buoyed and dropped into 25 feet of water by a Navy dive team. Three boats ran sonar search lines over the area. At the end of the day, the same dive team retrieved the debris. Sonar data was reviewed that afternoon. Two of the larger pieces were distinguishable in the sonar return but the smaller two pieces were not.

On March 4, the same dive team dropped three of the same four pieces, again buoyed with light nylon. The largest piece wasn't dropped since it was determined that the sea state made handling it dangerous for the divers. This location for the second drop was more challenging for the sonar operators due to the bottom being populated with more trees and stumps and a greater variation in topography. The wind was stronger that day and only one multibeam boat was able to make passes on the targets before the time came to collect the debris and return it to Lake Nacogdoches. As the divers went to retrieve them, they noted one of the three witness buoys was missing. The two pieces that were still buoyed were quickly retrieved but even after a number of dives, they were unable to find the last unbouyed piece.

Ashore, the analyst reviewed that morning's multibeam data trying to establish the location of the remaining piece. The piece, which was the largest of the three pieces dropped that day (measured 0.8 x 0.7 meters), was not distinguishable from the other debris on the bottom. Divers re-entered the water at 1530 and dove on the position the material was originally placed. Using a sector scan sonar, they directed the diver to all the possible targets. Using this process, the debris was found rather quickly. It had landed on the side of a creek bed and was nearly 50% silted in.

The difficulty the search team and dive team experienced in finding actual shuttle debris in a known location confirmed the challenge the organization faced in finding similar sized debris in a 14+ square nautical mile search area on the reservoir bottom. The recognition of this challenge led to a series of follow-on tests, described in detail in Chapter 3 and Appendix D. These tests were conducted to ensure the Navy was using equipment and processes that could be successful in recovering items the size of the OEX recorder, NASA's highest priority at the time.

Results from the third set of tests, conducted on March 15 and 16, provided graphic proof that some of the systems and processes were better able to obtain results in the Toledo Bend environment than others. Given that the size of the OEX Recorder was less than the size of a desktop PC housing, operators and equipment that were unable to consistently detect and discriminate targets of that size were removed from service. Specifically, in this environment, the standard Marine Sonic Centurion Sonar with a 5-degree downward transducer was much less capable than either the Klein 3000 or the custom Marine Sonic Centurion operated by IET of Mill Creek, WA.

Lesson: Ensure the equipment and processes employed can achieve the desired results and recognize unique capabilities and qualities in available assets.

4.2.4 Experience Counts

When the Navy assumed control of the Columbia Shuttle water search operation, they inherited not only the teams of divers, search assets, and support organizations already on the scene, but also all the side scan data and target lists that had already been generated. These target lists were incorporated into the integrated target plot database. As graphically portrayed in Figure 3-17, a target plot from inherited data, the initial sonar analysts were challenged to select valid targets from a bottom that was extensively cluttered with stumps and trees. This hostile bottom terrain presented a difficult challenge to even the most experienced analysts. When Phoenix assembled the analysis lab, affectionately referred to as the Voodoo Lounge for the magic they performed, they dedicated some of the most experienced analysts in the industry to the task of target identification. This experience coupled with the best technology available significantly reduced the number of non-man made targets passed to the divers for inspection and led to more efficient utilization of the diver's bottom time.

Lesson: In a complex acoustic environment such as Toledo Bend, ensure that the individuals performing sonar analysis/target identification are the most experienced analysts available.

4.2.5 Advanced GIS Plotting

Geographic Information Systems (GIS) is a relatively new science. Technological and software advances are pushing the technology to new applications. During this operation, SUPSALV had the opportunity to exercise their GIS expertise and to work with some very talented individuals who were trained in the latest processes and used GIS systems as a routine part of their job. These individuals were provided through the U.S. Forest Service as a part of the National Interagency Coordination Center (NICC). These GIS operators were generally U.S. Park Service or Bureau of Land Management personnel who were trained to provide the GIS positioning and plotting in support of forest fire fighting teams.

Lesson: In future search and recovery tasks where GIS requirements may exceed SUPSALV/Phoenix resources, SUPSALV can contact NICC to determine availability of backup GIS assets that may be able to assist with the task at hand. They can be reached through their website at www.nifc.gov.

4.2.6 Accurate Positioning is Critical

In every search, especially in a low visibility environment, it is imperative that the position of targets be accurately determined and that the divers dive on the right spot. To achieve the required accuracy, the C-Nav GPS systems were deployed on all search boats. These differential systems are survey grade and accurate to within 0.6 meters (10cm post-process). The search operators spent considerable time ensuring the search systems were correctly correlated with the navigation equipment. This included verifying that the antenna and fish "layback" and "offset" were accurately calibrated. On the diving side, the dive teams also used differential GPS systems. The drop boats appeared to be very effective in putting a buoy on the targets. The dive boats which didn't have dedicated drop boats had to get used to dropping a buoy on target before dropping the boat's anchor and sector scan. If they didn't put a drop buoy down, the diver was very challenged to find the selected target among the stumps and bottom debris.

Lesson: In limited visibility environment, ensure best positioning practices are consistently utilized and each boat's equipment is calibrated daily.

4.2.7 Supply Chain

At the start of the operation, Phoenix personnel facilitated procurement of supplies using their personal credit cards. No Government Impact Card was deployed with the MDSU TWO detachment. This resulted in a dysfunctional procurement system. Phoenix also lacked any administrative/supply personnel and the project manager was forced to resolve each material issue. After a couple of weeks, Phoenix took steps to resolve the supply issue by staffing the project with a logistics professional. He was able to work effectively with the local merchants and fully engage the home office supply organization. As local vendors were identified, Phoenix established commercial accounts and ceased the use of employee credit cards. Local vendors included: boat rental, local welder who repaired boats and trailers, office supplies, fuel delivery, and the nearest large marine supply store, among others. Many of these local suppliers, recognizing the nature of the operation and the immediate needs of the Navy, began delivering their goods directly to the Fin and Feather, allowing the search teams to operate more efficiently.

Lesson: Manning the project with professional logistics support at the start of the operation and early formalization of business relationships with local vendors is as critical to support of the operation as providing professional search and diving personnel.

4.2.8 Community Relations Pay Dividends

From the first day of the incident, NASA and the recovery teams received generous support from the local community. Local volunteers and organizations aided in the search efforts and many individuals from the community supported the searchers with food and other offers of assistance. Both the diving and the search organizations were offered space in the local fire station to serve as a base of operations. The Navy

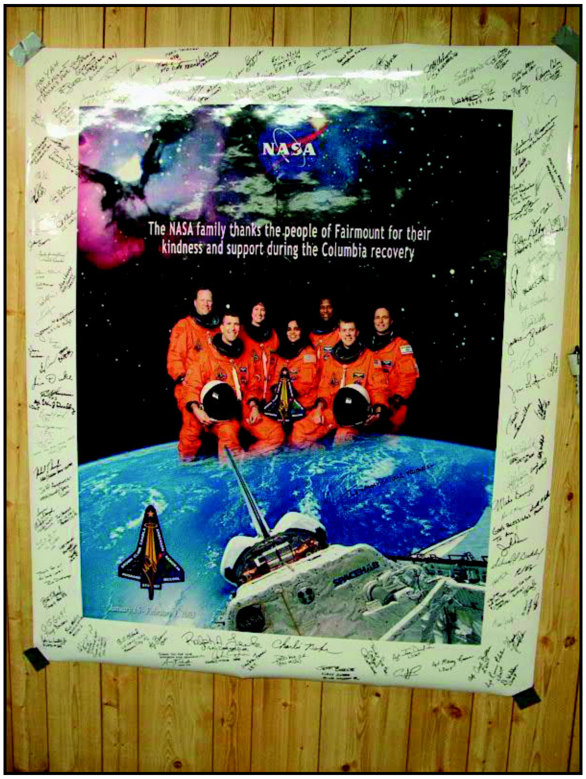


Figure 4-7. Poster of STS-107 Crew Signed by Water Search Team and Presented to the Fairmount Community.

recognized the importance of this local support, especially in a rural area like East Texas, and worked to ensure these relationships were fostered and maintained. One of the ways the Navy helped maintain the relationship was hosting a BBQ for the community, especially those who provided meals at the firehouse. This event, held at the Fin and Feather Restaurant and supported by an astronaut speaker, was well attended by the community and considered a great success. NASA produced a large poster of the Columbia crew and the water search organization signed the poster and presented it to the community as a recognition of their contribution. Figure 4-7 is a photograph of the poster. The Navy also ensured that any damage caused by all the truck and boat trailer traffic at the Paradise Point Marina was repaired. These steps paid dividends as the local residents continued to enthusiastically greet and support the water search teams for the entire period they were in Texas.

Lesson: Good public relations is well worth the effort it requires. Support of the local community goes a long way toward the conduct of a smooth operation.

4.2.9 Efficient Data Operations Require High End Support

Normal modern search and recovery operations are data intensive. This operation was no exception and pushed the envelope to new heights. With as many as seven search boats and eight dive boats on the water each day, the amount of data being processed in a 24-hour period was immense. The search management operation began inside the Six Mile Fire Station where conditions were damp, cold, and crowded. Plotters and PCs do not operate at their best under these conditions. The move to the Fin and Feather was a substantial improvement in facilities and allowed a significant upgrade in the IT infrastructure. FEMA and NASA helped ensure that data management operated efficiently. This support included the full networking of the data center, a T1 communications line, and provision of a high volume color plotter and copier. As more than 100 megabytes of data were transmitted to Lufkin and more than 20 large-scale, color plots were generated daily, high quality IT support was an absolute necessity.

Lesson: Ensure that planning for operations of this type include provisions for use of high speed information technology and data transfer equipment with adequate climate control for protection of the equipment. A skilled, professional, IT installation team should be on-site before the operation begins.

4.2.10 Expert Consultation

In addition to the experienced staff assembled for the project, the SUPSALV team requested ideas and assistance from outside experts. These individuals not only validated the credibility of the Navy-led search plan but also offered ideas to improve the process. A table of activities who contributed toward validation and improvement of the search process are provided in Figure 4-8.

AREA OF EXPERTISE	CONSULTED ACTIVITY
General Search Ideas and Guidance	• Scripps Institution of Oceanography • Woods Hole Oceanographic Institute (WHOI) • National Oceanic & Atmospheric Administration (NOAA) • Office of Naval Research (ONR)
Specific Search Systems, Including Side Scan and Multibeam Systems	• Quester Tanget Incorporated • Dr. Larry Mayer of University of New Hampshire. • Thales GeoSolutions (Pacific), Inc.
REMUS AUV	• NOAA Coast Survey • WHOI
Sector Scan Implementation	• Kongsberg Simrad Mesotech Ltd./C.A. Richards

Figure 4-8. Table of Consultants Supporting Columbia Water Search Operations

Lesson: Don't hesitate to use any and all areas of expertise that can be brought to bear on the problem at hand.

4.2.11 Document the Process

SUPSALV identified the need to document the operation within the first week of their recovery effort in Texas. They arranged to have their administrative support contractor, ROH, Incorporated, send a technical writer on-scene within days to begin collecting data, images, and interviewing the key individuals involved in the decision making process. The early identification of the requirement to document the process has resulted in this timely summary of events, processes, and lessons learned which might have been lost or delayed without a dedicated observer and recorder present.

Lesson: Include a dedicated technical writer in the manning of future high-visibility, complex recovery operations.

4.2.12 Accountability for Material

After the operation was secured, the final disposition of a large quantity of equipment and material purchased for operational support could not be accounted for.

Lesson: An on-site inventory control system that tracks and accounts for all incoming material should be instituted for all field operations. A signature custody log for tracking material disposition should be part of the overall system.

Results

Section 5
Results

Given the terrain and the generally small size of the average piece of shuttle debris, retrieval of all space shuttle components was neither expected nor possible. Even though the preponderance of debris fell on land, NASA's ground search effort, utilizing more than 16,500 searchers and searching an unprecedented 680,748 acres, collected less than 40% of shuttle material by weight. A second factor affecting the water search team's chances in recovering shuttle debris was the quantity of debris encountered as the searchers moved east toward Toledo Bend Reservoir. Figure 5–1 is a cropped version of the scatter plot presented as Figure 1-1. This figure shows that the maximum density of the debris field was well to the west of the Toledo Bend area.

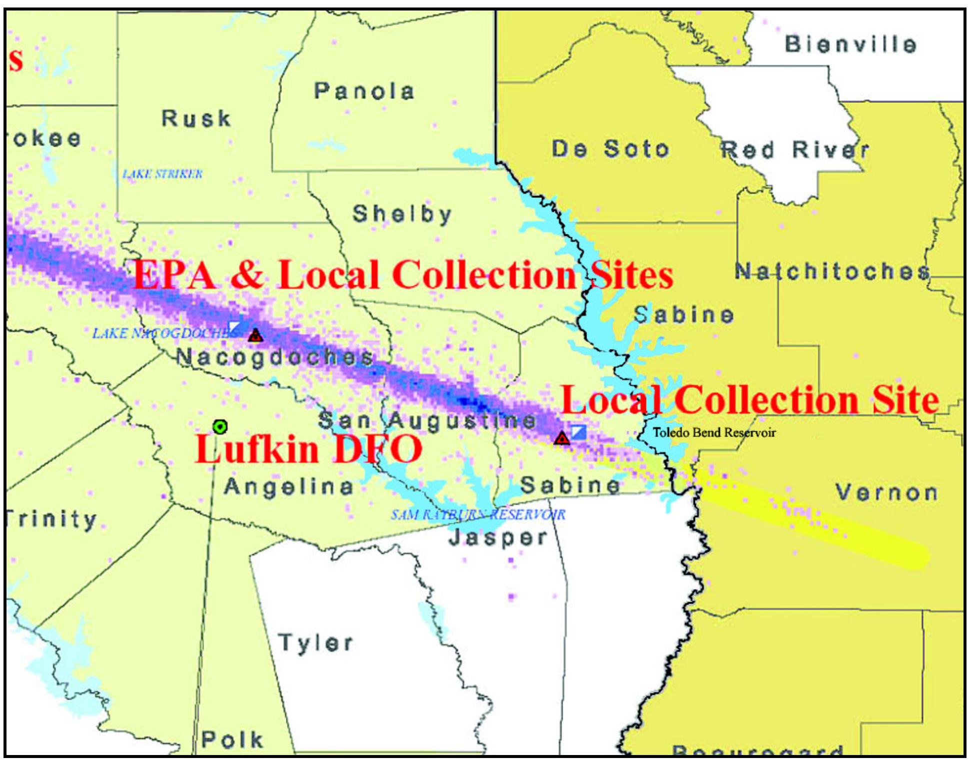


Figure 5-1. Space Shuttle Debris Distribution as of May 2, 2003.

Faced with these challenges, the Navy committed to provide its best effort to retrieve all shuttle debris that was possible from the two lakes in East Texas. After a thorough search of the water areas, the following conclusions can be made:

- Large, intact sections of the shuttle did not land in the lakes within the primary search areas. If they had, the Navy-led water search and recovery teams would have found it.
- Small and medium size pieces that may have fallen into the lake could not be retrieved using today's technology and within the reasonable constraints of time and resources, i.e., draining the lakes.

5.1 Debris Recovered

What did the water search team accomplish? From the first week when FBI divers, responding to an eyewitness report, recovered a brake component on the eastern shore of the Toledo Bend Reservoir through the last week of the operation where grid searchers painstakingly searched specific high probability areas inch by inch, the water search organization set about their tasks with enthusiasm and professionalism.

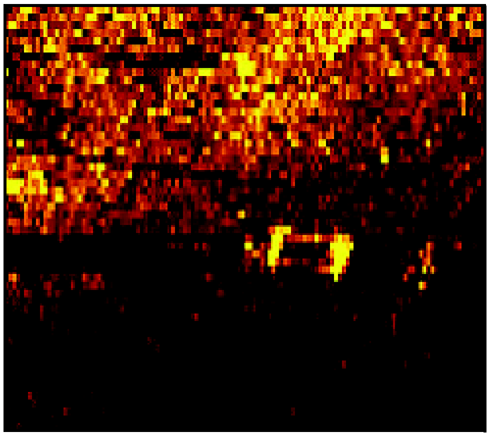
During the first few weeks of the operation the sonar analyst achieved a high degree of proficiency in their ability to distinguish between the sonar return characteristics of the natural debris and the man-made debris on the lake bed. After a tuning process the search teams began to consistently identify man-made objects as targets and divers began to routinely find and retrieve these man-made targets. Almost as a point of pride, the recovered targets were lined up against the north wall of the Command Center like trophies. These items included an old fish trap, anchors, a number of outboard motors, a wheel, a radiator, and a refrigerator door. Figure 5–2 shows some of the pieces of recovered debris and Figure 5–3 provides examples of sonar imagery of some of the man-made objects targeted on the lake floor. These sample sonar images and actual man-made debris included large items like the boat and the truck body, and small items like a drywall bucket. The search team's ability to detect (calibrated equipment) and discriminate (experienced analyst) these targets and the diver's ability to locate and retrieve the targets are proof that the SUPSALV search and recovery plan was effective. The items found were similar in size to the actual shuttle targets NASA identified as high priority.

Figure 5-2. Examples of Man-made Debris Recovered from Toledo Bend.

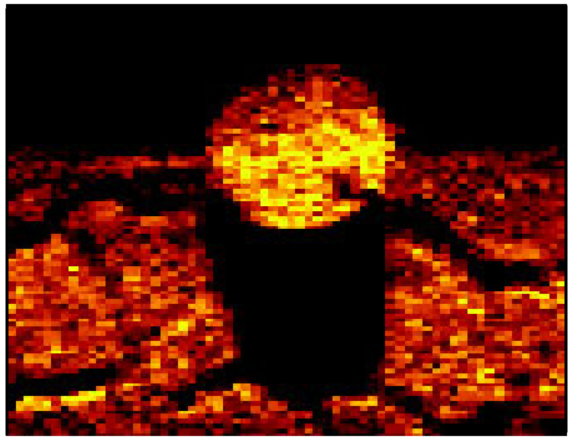
5.2 Thorough Search Conducted

A few weeks into the operation, it was recognized that the water search team was identifying and retrieving man-made targets regularly, but shuttle debris was, as of yet, undetected. SUPSALV began asking the questions:

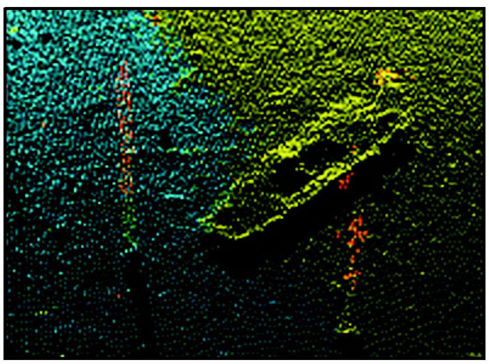
- Is there anything that can be done differently to find the shuttle debris?
- Is the water search being conducted as proficiently and thoroughly as possible?



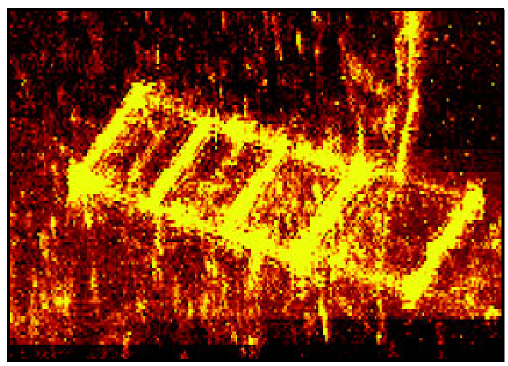
Refrigerator Without a Door



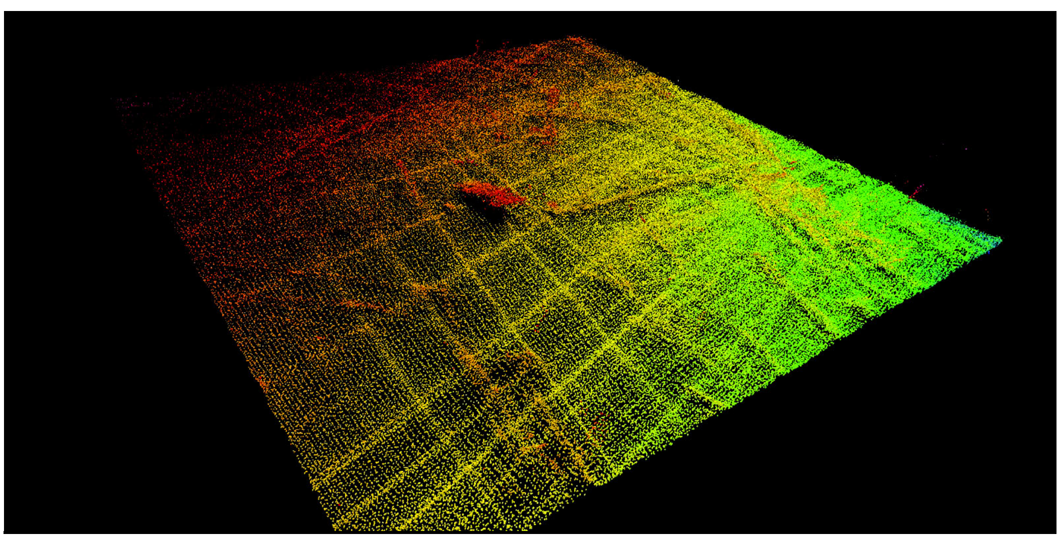
5 Gallon Bucket



Boat



Metal Frame



Pickup Truck

Figure 5-3. Sonar and Multibeam Imagery of Man-made Objects Found in Toledo Bend Reservoir.

The answer to the first question was to ensure the search teams were using the best equipment, software, and techniques available. To ensure this was the case, SUPSALV consulted established industry experts listed below:

- Scripps Institution of Oceanography
- Woods Hole Oceanographic Institute (WHOI)
- National Oceanic & Atmospheric Administration (NOAA)
- Office of Naval Research (ONR)
- Center for Coastal and Ocean Mapping, Chase Ocean Engineering Lab at University of New Hampshire.

SUPSALV also enlisted the resources of the following private firms that manufacture or use such search tools and are recognized experts in the field:

- Quester Tanget Corporation
- Kongsberg Simrad Mesotech Ltd/C.A. Richards
- Thales GeoSolutions Inc.
- C&C Technologies

After consultation with these experts, SUPSALV was confident that the search process was as effective as possible and alternative solutions were not available that would increase the likelihood of finding shuttle debris.

To qualify an answer to the second question on water search proficiency, the following anecdotal evidence is provided. There were some areas that NASA identified as high priority and on which the Navy was asked to concentrate. In these areas, like the radar-projected high probability debris landing sites in Eastern Toledo Bend Reservoir, the water search team provided 200 or 300 percent coverage with the best search assets for those conditions. As an added measure, grid searches were performed in two specific locations. These were in response to an eyewitness account and based on the recovery of two pieces of a shuttle camera nearby on the ground. The 88 grids searched in these two areas comprised 5.5 acres. This process took 176 diving hours and yielded only a single piece of shuttle skin, the size of a thumbnail.

This extraordinary effort validated that the primary search methods (sonar and multibeam systems) used prior to the grid search did not miss any significant sized shuttle pieces and that due to the low density of shuttle debris in Toledo Bend Reservoir, there was a low probability of finding actual debris even if the grid-search method were used throughout the initial 14.7 square nautical mile primary search area. The time to grid-search the entire Toledo Bend primary search area would exceed 16,000 diving days.

5.3 Operation Statistics

On March 18, 2003, NASA recognized that the water search was not going to find the same type debris that was being found on land and asked the Navy to develop and execute a plan for completion of the primary search area by April 15, 2003. SUPSALV concluded search operations on Toledo Bend Reservoir on April 11 and diving operations on April 12, 2003. The significant statistics associated with the operation appear in the tables below.

	Lake Nacogdoches	**Toledo Bend**
Dates Searched	17 Feb - 10 Mar	5 Feb – 10 Apr
Dates Dove	9 Mar – 26 Mar	4 Feb – 11 Apr
Area Searched	3.17 sq. mi.	20.14 sq. mi.
Linear Search Track	1563 nM	2343 nM
Targets Cleared	365	2734
Positive Shuttle Targets	0	2

Organization	**Number of Dives**	**Bottom Time (hrs)**
U.S. Navy	1334	320
Houston Police Department	596	128
Environmental Protection Agency	421	193
Department of Public Safety	328	133
Galveston Police Department	241	53
Total	2,920	827

LIST OF ASSETS

List of Assets

DIVE/SEARCH BOATS

USCG 32 Foot

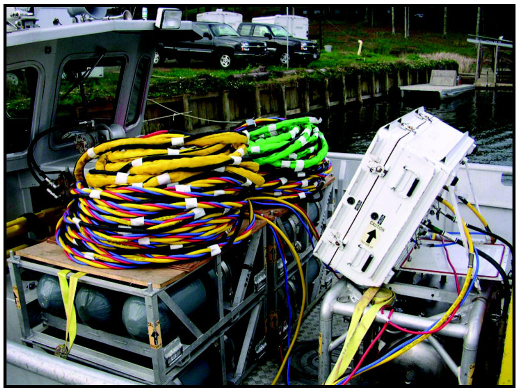
Dive Boat

Dive Boat

Side Scan Boat

Source for boats included:	Local Search Contractors, Dive teams, U.S. Coast Guard, and from Gulf Coast boat rental firms.
Length:	22 - 26 ft
Hull material:	Aluminum, Steel, GRP
Power:	Single or Twin Engine Outboards
Accommodations:	Cabin to support electronic search equipment and protect divers from elements.

Light Weight Dive System (LWDS)



LWDS Gear

DIve Boat Outfitted with LWDS

Diesel-Compressor Assembly

40"x48"x66", 650lbs

Capacity 18.6 scfm @ 175 psig

Primary HP Air Supply (each flask rack assembly)

24"x40"x46', 200lbs

Capacity 573 scf @ 3,000 psig

Volume Tank Assembly

46"x29"x28", 250lbs

Capacity 30 gallons

(4 cubic feet) LP-250 psig, HP-3,000 psig

Control Console Assembly

17"X31"X33", 150lbs

Capacity LP-250psig

HP-3,000 psig

Secondary HP Air Supply (each flask rack assembly)

24"X40"X46", 200lbs

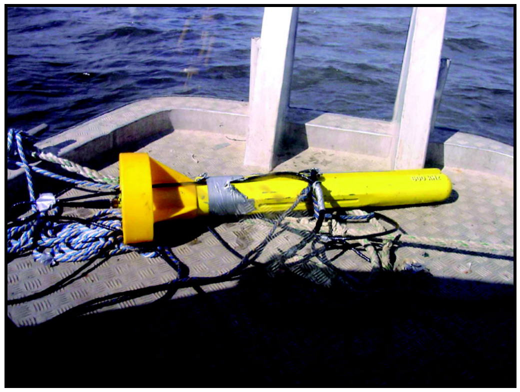
Capacity 573 scf @ 3,000 psig

Roof Rack Assembly

11"X40"X46", 50lbs

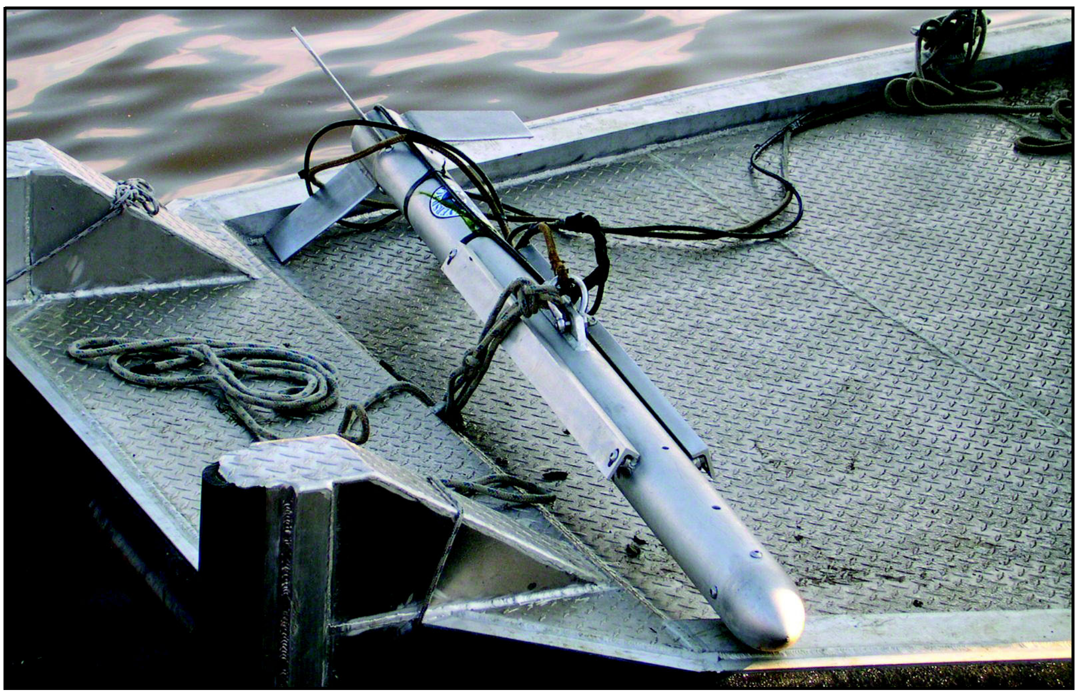
Capacity 3,000 psig

Marine Sonic Centurion Side Scan Sonar



Standard 5^o Marine Sonic Side Scan

Standard 5^o Marine Sonic Side Scan, Pole Mounted



Custom 10^o Marine Sonic Side Scan

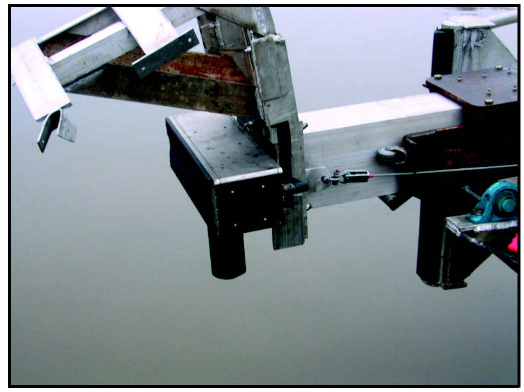
Length (m/in):	1.1/42
Diameter (cm/in):	10.2/4
Weight in air (kg/lbs):	15/33
Pulse Length (usec/cycles):	10/6
Range resolution (cm/in):	9.7/3.8@50m
Axial Resolution-aperture size (cm/in):	30.5/12
Max Range (meters):	75+
Frequency Options:	150, 300, 600, 900, 1200 kHz

Klein 3000 Side Scan Sonar

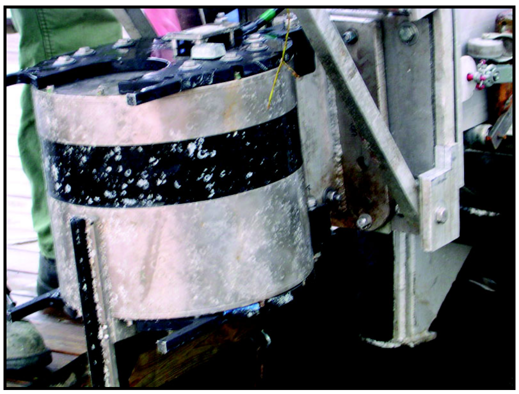
Frequencies:	100 kHz (125 kHz +/- 1% act.), 500 kHz(445 kHz, +/-1% act.)
Beams:	Horizontal - 1 deg. @100 kHz, 0.2 deg @ 500 kHz, Vertical - 40 deg
Beam Tilt:	0, 10, 20 degrees, adjustable
Maximum Range:	450 meters @ 100 kHz; 150 meters @ 500 kHz
Depth Rating:	1,500 meters
Construction:	Stainless steel
Size:	122 cm long, 8.9 cm diameter
Weight:	29 kg in air
Options:	Sub-bottom profiler, Magnetometer, Attitude sensors: roll, pitch, heading, pressure, attitude, acoustic positioning responder, single frequency of 50 kHz

Reson Seabat 8101 and 8125 Multibeam

8101 Multibeam



8125 Multibeam



8101 Multibeam

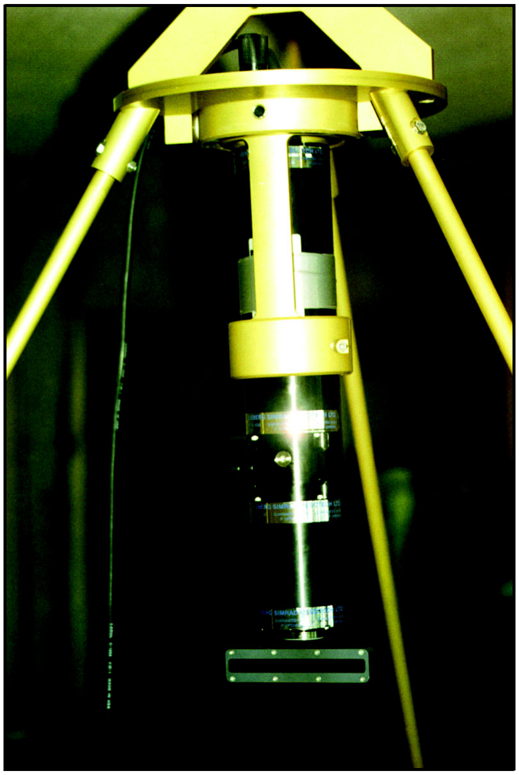
8125 Multibeam

	8101	8125
Beam Width:	1.50^{o}	0.5^{o}
Number of Beams:	101	240
Swath Width at 10 M Depth:	68.80(M)	30.60(M)
Operating Frequency	240 kHz	455 kHz

Hydroid Remote Environmental Monitoring Unit (REMUS)

Diameter:	19 cm
Length:	160 cm
Weight in air:	37 kg (80 lbs)
Trim weight in air:	1 kg
Max operating depth:	100 meters
Energy:	1 kw-hr internally rechargeable lithium ion battery
Endurance:	22 hours at optimum speed of 1.5 m/s (3 knots) 0.8 hours at 2.5 m/s (5 knots)
Propulsion:	Direct drive DC brushless motor to open three bladed propeller
Velocity Range:	0.25 to 2.8 m/s variable over range
Control:	2 coupled yaw and pitch fins
Navigation:	Long base line; ultra short base line; Doppler assisted dead reckon; (Optional: GPS)
Transponder:	20-30 kHz operating frequency range
Tracking:	Emergency transponder, mission abort, and ORE Trackpoint compatible
Sensors:	Doppler velocity log: RDI 1.2 MHz up down looking
Side Scan Sonar:	600 or 900 kHz Marine Sonic

Kongsberg Simrad Mesotech LTD MS 1000 Sector Scan



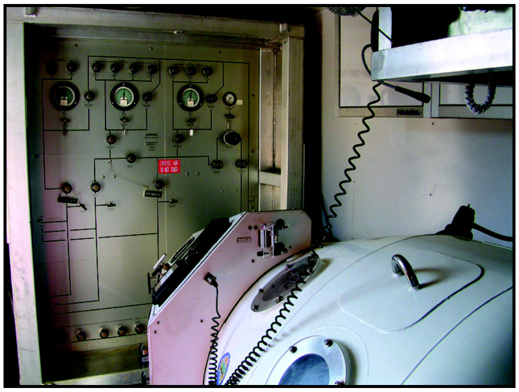
Close up of Sector Scan Transducer

Deploying Sector Scan Unit

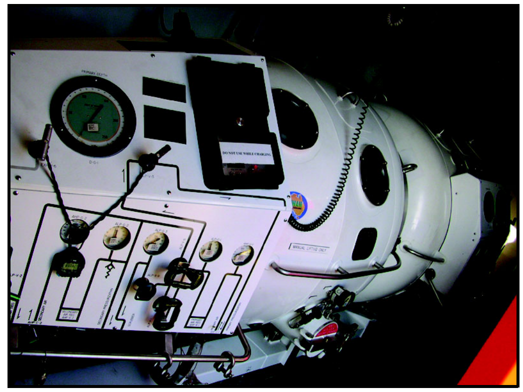
Sector Scan Unit Mounted on its Tripod Staged on Bow of Dive Boat

FREQUENCY:	675 kHz
BEAMWIDTH:	1.35 x 30^{o}
RANGE:	0.5 to 100 m
TELEMETRY:	Standard/low frequency and digital
DEPTH RATING:	6000 m
LENGTH:	298 mm
DIAM:	139 mm
WEIGHT:	
IN AIR:	5.3 kg
IN WATER:	2.5 kg

Transportable Recompression Chamber (TRCS)



TRCS Panel



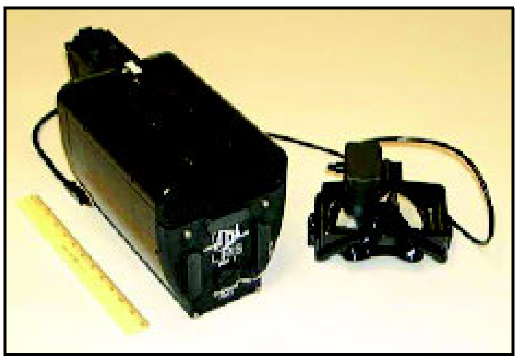
TRCS Unit

TRCS rigged for transport

Design Code:	AS1210/ASME PVHO
Design Pressure:	110 psig
Certification pressure:	100 psig (225 fsw)
Design Temperature:	0-125^{o} F
Length:	90.2" (95.7" with strongback)
Height:	52.6"
Width:	50.7"
Weight:	1,268 lbs
Internal Volume:	45 cu. Ft.
	Medical Lock 5.75" inside dia. X 11.8" long
Mating Flange:	Male per NATO, A Div P-1
Chamber lift padeyes:	MIL-STD-209
Chamber Tie Down padeyes:	MIL-STD-209
Materials:	
Heads, Doors, Shell:	ASTM A240 GR S31803 stainless steel
Forgings and Mating Flanges:	ASTM A182 F 316L stainless steel
Medical Lock:	ASTM A240 GR S31803 stainless steel
Life Support:	
Scrubber:	Air driven with replaceable canister
BIBS:	2 Masks-chamber oxygen/air supply/mixed gas, and overboard exhaust
Gas supply:	Primary and secondary air, and primary and secondary oxygen
Furnishings:	Patient stretcher and attendant's seat

Limpet Mine Imaging Sonar (LIMIS)

Pond search conducted with LIMIS

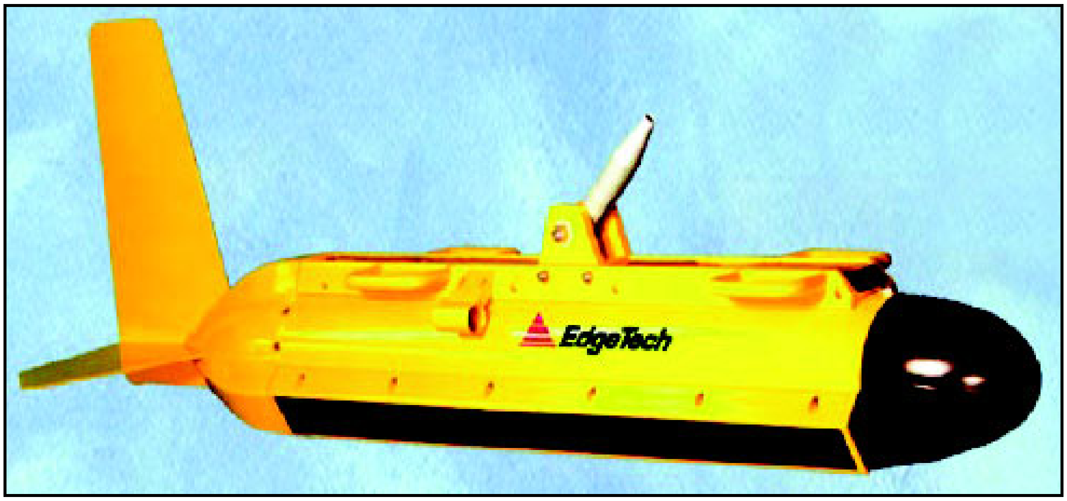


LIMIS Unit

Diver utilizing LIMIS system

Cross-range resolution:	1.6 cm at a 3-m range
Beamwidth:	0.3 degrees horizontal by 7 degrees vertical
Number of beams:	64
Field of view:	19.2 degrees
Range settings:	3-15 m, 1.5-8 m, 1-3.6m, 0.6-2m
Down-range resolution:	2.5 cm, 1.25 cm, 0.6 cm, or 0.3 cm depending on range setting
Operating frequency:	2 MHz
Power consumption:	25W (1.75 A at 14.4 V)
Weight:	7.7 kg in air, including internal batteries; and 100 g positive in sea water
Dimensions:	17.8 cm wide, 20 cm high, and 35 cm long, including a 10 cm handle.
Output:	NTSC video on a mask-mounted video monitor and/or cabled topside.

Edgetech MPX Multi-Pulse Side Scan Sonar



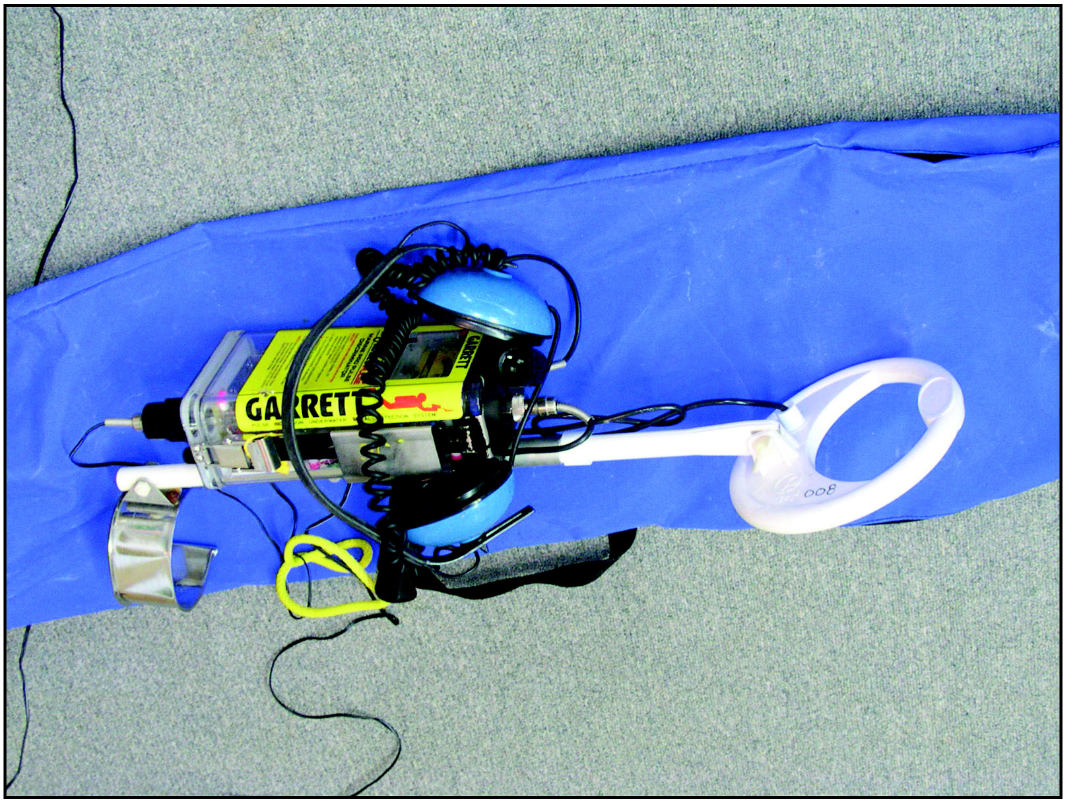
Frequency:	270 kHz
Pulse Type:	Full Spectrum FM
Towing Speed at 100 Meter Range:	up to 16 knots
Maximum Operating Range:	225 meters per side (450 meter swath)
Maximum Operating Depth:	300 meters
Pulse Repetition Rate:	14 / 28 at 100 meters
Horizontal Beam Width:	0.75 meters at 100 meters
Resolution Across Track:	0.075 / 0.15 meters
Length:	(L) 173 cm x (H) 37 cm
Diameter:	19 cm
Weight (in air):	60 kg
Weight (in water)	20 kg

AN/PQS-2 Alpha Hand Held Sonar

Range Active Mode:	20, 60, or 120 yards (108 meters)
Range Passive Mode:	2000 yards (1800 meters)
Acoustic Frequency:	CTFM, 115 TO 145 kHz (30 kHz bandwidth)
Passive Detection:	Can detect acoustic signal with source level of 120 dB/μ at 1 meter at 39 kHz at ranges up to 1 mile
Passive Frequency:	Variable 24 to 45 kHz range
Magnetic Signature:	Meets requirement of MIL-M-19595
Output Technique:	Audio Tone (or pulse) in earphones, frequency variable with range
Power Source:	Two rechargeable gelled electrolyte lead acid batteries
Operating Depth:	Surface to 300 feet (91 meters)
Operating Temperature:	From -2 deg C to +30 deg C
Beamwidth:	6 Degrees (can detect a 12 inch diameter air filled sphere at 120 yards)
Weight In Air:	Approx 8 lbs (3.6 Kg)
Weight In Water:	Slight negative buoyancy

Unit equipped with a magnetic compass (Does not meet low-Mu spec)

Garrett Sea Hunter XL Hand Held Metal Detector



Weight:	
Housing	3.8 lbs
Headphones	1.4 lbs
Coil	2 lbs (negative buoyancy in water)
Depth Rating	65 Meters
Detector Coil	8" Diameter
Frequency	110 pulses/second

TIMELINE OF EVENTS

Timeline of Events

1 Feb	• Columbia Shuttle breaks apart during reentry • Search begins • SUPSALV (CAPT Wilkins) U.S. Navy Command Center at Pentagon offering assistance
2 Feb	• Considered lake areas as a part of the search
3 Feb	• EPA, US Coast Guard and Forest Service representatives visit Toledo Bend Reservoir in attempt to find debris reported by eyewitness
4 Feb	• Dive assets arrive on scene • FBI ROV on scene • Sighting of large objects by air investigated. No success finding shuttle debris
6 Feb	• DOJ tethered submarine (ROV) arrives
7 Feb	• Houston Police and EPA dive teams arrive • EPA contracted search teams arrive • Informal EOD assessment of Navy support provided
8 Feb	• Moved water search operations from Indian Mounds to Fairmount Volunteer Firehouse • Conference call with CAPT Wilkins, NASA, and EPA resulted in SUPSALV requested formal assessment
9 Feb	• CAPT Wilkins, CAPT Murray, Tom Salmon, and Ridge Albaugh visit area for the first time. Meet with EPA Scott Harris and NASA Steve Bowen. Visit firehouse and lake. • Texas Forest Service arrives to handle logistics
10 Feb	• Brief agency reps including FEMA Federal Coordinating Officer (FSO) on SUPSALV & Navy capabilities. FCO approves SUPSALV proposal. • Diving assets on scene at the time are EPA, Houston PD, FBI, Galveston Sheriff, Galveston PD, and Texas DPS. Support included CG, Sabine RA • Scanning teams consist of two EPA contracted assets • FBI divers recover brake assembly from Toledo Bend. • Noted non-standard GPS systems, no search coordinates established, eye witness and land based debris, no clear organization for deployment of assets • SUPSALV temporarily departs for NAVSEA Headquarters
12 Feb	• Conduct air recognizance of Sam Raburn Res. Lake Nacogdoches, Lake Striker, Lake Cherokee, Toledo Bend • CAPT Murray moves base of operations from Lufkin to Toledo Bend area • Custom Marine Sonic arrives
13 Feb	• Navy is tasked to search lakes and reservoir for shuttle debris by CNO verbal message • First MDSU team members arrive (lead party), Lee Wolford arrives in TX, Tom Salmon departs • 6 dive teams still on station (civilian)
14 Feb	• COMLANTFLT tasks MDSU TWO • SUPSALV tasks PHEONIX to support search and recovery operations • SUPSALV returns to Lufkin, TX. • One dive team sent to Lake Striker and Lake Nacogdoches based on eye witness reports. Checked out false dock strike
15 Feb	• 16 MDSU divers arrive, 1 combat camera diver arrives • Navy begins issuing SITREPS
16 Feb	• MDSU 2 Recompression Chamber arrives
17 Feb	• Side scan search begins at Lake Nacogdoches

18 Feb	• MDSU2 starts diving, SUPSALV/Phoenix begin processing target data
19 Feb	• Press Conference on Underwater Search • Forward strut assembly found ashore adjacent to reservoir • Houston PD using sector scan sonar
21 Feb	• 4 sector scan sonar arrive • NASA expands water search area to include Bardswell Lake and Lake Waxahachie (Western end of debris line)
22 Feb	• Reson Multibeam arrives
23 Feb	• Second sector scan put into use
24 Feb	• Reson Multibeam begins operations • Requirement to search Lakes Bardwell and Waxahachie deferred
26 Feb	• Columbia Operations Command Center moved from Fairmount Fire House to Fin and Feather • Reson Multibeam search system put into service • Kline 3000 begins running lines at Lake Nacogdoches
27 Feb	• REMUS arrives on site
28 Feb	• REMUS begins searching • Microwave transmitter tower installed at Fin and Feather • DIDSON imaging sonar arrives on site • Additional set of portable radios ordered
1 Mar	• Local pond is searched by a dive team • 20-meter search line spacing decreased to 15 meters
2 Mar	• Run test on 4 pieces of shuttle debris
3 Mar	• Test on 4 pieces of shuttle debris completed • Debris in pond found based on eye witness sighting
4 Mar	• Multibeam 8101 being mounted on C&C 3
5 Mar	• Redraw of search map reduced primary search are to 14.7 sq mi
6 Mar	• Conduct controlled test on metallic objects with Seabat 8125 and 8101 multibeam
7 Mar	• MDSU 2 begins surface supplied diving on Toledo Bend Reservoir • Gas tank at F&F placed on line • Second REMUS arrives
8 Mar	• Gas tank at F&F operational • Divers instructed to recover “manageable” size targets if they will not interfere with dive boat operations • Operations on Lake Nacogdoches expected to wrap up Sunday 09March03 • Additional REMUS unit brought into Command Center • FEMA tech personnel arrive to install additional network drops increasing com center functionality
9 Mar	• Last day of Lake Nacogdoches search
10 Mar	• Lake Nacogdoches searching completed • At Lufkin center briefing report came in of a partially submerged tank in a pond visible from the air. USN assets may be employed to locate it.
11 Mar	• Signs posted on cars at local marinas asking boaters to use caution and maintain No Wake around search and diving boats. Signs also have number of Lufkin field office to call to report debris.
12 Mar	• Meet with the sonar and multibeam experts to discuss the situation in Toledo Bend and examine options and possible solutions. Drs. Larry Mayer and Brian Calder from the Univ of NH, Eric Maillard from Reson (8125,8101), Doug Lockhart from Thales Inc., and Thomas Chance CEO of C&C Survey. • Doug Lockhart, Lee Wolford and Ridge Albaugh create a test plan to prove the Sonar systems
13 Mar	• Meeting in Lufkin with heads of all aspects of recovery and local officials

14 Mar	• Phase 2 - search plan altered at NASA direction to only search Toledo Bend reservoir with sidescan and multibeam only once (change from Lake Nacogdoches and Toledo Bend searched with sidescan and multibeam both horizontally and vertically)
15 Mar	• Tested Echo Star sonar in Toledo Bend
16 Mar	• Began deepwater sonar testing in Toledo Bend
17 Mar	• Edgetech MPX system brought in and tested • All systems finished on sonar test ranges
18 Mar	• Demobilize the 5-degree 600 Khz MS sonar
19 Mar	• Second Kline 3000 arrives • CAPT Wilkins calls Chief of Navy Research (CNR), Woods Hole, Scriptts Institute, and NOAA for 21 March meeting of subject matter experts. • Vodoo Lounge will begin producing a daily "top ten" target package for the divers. • Astronaut Jim Reilly says it is important to keep all digital data for possible reexamination at a later date
20 Mar	• OEX recorder found in woods 8 miles west of Toledo Bend • Standard Marine Sonic taken offline • Galveston PD dive team departs
21 Mar	• Ben Evans and Justin Manley from NOAA, Tory Cobb from Coastal Systems Station Panama City (recommended by ADM Cohen) Dave Chadwell from Scripps and Dr. Larry Mayer from Univ of NH, Keith Russel from NASA, WHOI and ONR representatives meet to discuss possible methods to improve search process.
22 Mar	• Second Kline begins search efforts • REMUS analysis completed by NOAA Office of Coast Survey
24 Mar	• NASA Administrator Sean O'Keef visits
25 Mar	• NASA photographer visits • Severed Klein tow cable – lost towfish
26 Mar	• REMUS engineer from WHOI working with REMUS crew
27 Mar	• Exit Strategy meeting in Lufkin • Georgia Department of Natural Resources Klein 3000 arrives • First Klein3000 towfish recovered by Houston Police
28 Mar	• REMUS completes final operations and demobilizes
29 Mar	• Weather day, no ops
30 Mar	• Weather day, limited ops
31 Mar	• Operations begin early, PM weather expected • Contacted manufacturer of the Geophex magnetometer. Manufacturer did not see it feasible to bring system here.
1 Apr	• Operations begin early, PM weather expected • Keith Russell of NASA says Jerry Voss not in favor of bringing more sensors into Toledo Bend • Still no decision on Geophex magnetometer
2 Apr	• Operations begin early, PM weather expected • New eyewitness report North of the recovery track investigated
3 Apr	• CAPT Murray will begin 90x90 feet grid searches of a selected section of Toledo Bend floor at the request of Astronaut Jim Reilly • Credible eyewitness debris sight being side scanned
4 Apr	• Ops end early due to Tornado warnings • Continue investigation of eye witness reports • Begin discussions of demobilization
5 Apr	• Weather cleared allowing for full day of dive and search ops. • Phoenix inventory specialist arrived to begin demobilization inventory process

6 Apr	• US Navy safety and repair stand down • Civilian dive teams continue to dive per their request • Side scan/multibeam search continues • Sonar analyses continue
7 Apr	• Normal search and dive operations continue
8 Apr	• Weather day (12-19 mph winds). Dive boats out, no search ops.
9 Apr	• Cold and very windy. Dive and search ops continue. • Prioritized list put together for the last days of searching • NASA presentation at 6pm
10 Apr	• Normal search and dive operations continue • Some MDSU reserves leave
11 Apr	• Search and dive operations continue • Last search day • Start search equipment demobilization • Sub-contractor demobilization and departure
12 Apr	• Last dive day • Search equipment demobilization continues • CAPT Wilkins departs
13 Apr	• Continue search equipment demobilization • Dive equipment cleanup and packing • Divers depart
14 Apr	• Search team demobilize and depart

CORRESPONDENCE, TASKING AND SAMPLE SITREPs

Request For Federal Assistance (RFA)

FEDERAL EMERGENCY MANAGEMENT AGENCY REQUEST FOR FEDERAL ASSISTANCE (RFA)	O.M.B. NO. 3067-0278 Expires February 29, 2004

I. TRACKING INFORMATION (FEMA Use Only)

State: Texas (TX)	Action Request #: 50-14064
Program Code/Event #: 3171EM, LOSS OF THE SPACE SHUTTLE COLUMBIA	Date/Time Recd: 02/10/2003 21:43

II. ASSISTANCE REQUESTED ☐ See Attached

Assistance Requested: In support of USEPA, provide search and recovery of Space Shuttle Columbia materials from Toledo Bend Reservoir, Sam Rayburn Reservoir and other local lakes, ponds and reservoirs identified through the course of the investigation. Assistance includes command and control (under USEPA) of the underwater search and recovery effort, as well as, personnel and equipment to augment current agencies on scene supporting underwater search and recovery.

Quantity: 1 (Each)	Date/Time Required: 02/10/2003 21:43	Internal Control #:

Delivery Location: Capt Jim Wilkins, 415 South 1st St., Lufkin TX 75901

Initiator/Requestor Name: John Martin	24-hour Ph/Fax #s: (936) 631-3684	Date: 02/10/2003
POC Name: DOD	24-hour Ph/Fax #s: (240) 351-8784	Date: 02/10/2003
*State Approving Official (Required for DFA and TA):		Date:

III. INITIAL FEDERAL COORDINATION (Operations Section)

Action to:	☐ ESF #: ■ Other:	Date/Time: 02/10/2003 21:51	Priority: ☐ 1 Lifesaving ☐ 2 Life sustaining ■ 3 High ☐ 4 Medium ☐ 5 Normal

IV. DESCRIPTION (Assigned Agency Action Officer) ☐ See Attached

Mission Statement: (Billing instructions are found on www.fema.gov/ofm under the subheading Federal Agencies Doing Business with FEMA.) Urgent, critical recovery of Columbia debris requires immediate establishment of command and control, as well as, operational augment of the on-ongoing underwater search and recovery effort from the several bodies of water contained within the debris field. In support of USEPA, US Navy Supervisor of Salvage & Diving (COMNAVSEA Code 00C, Washington DC) provide command and control of the underwater search and recovery effort, as well as, provision of additional US Navy assets and personnel to augment existing agencies' support Scope of operations includes search and recovery in the two major reservoirs currently identified as containing debris (Toledo Bend and Sam Rayburn), as well as other local lakes, ponds, and reservoirs suspected of containing shuttle debris. Navy POC: Capt Chris Murray 703.608-0978, Tom Salmon 703-625-2781. EPA POC: Scott Harris 214-789-9656.

Assigned Agency: DOD	Projected Start Date: 02/10/2003	Projected End Date: 03/10/2003
■ New or ☐ Amendment to MA #:	Total Cost Estimate: $3,000,000.00	
Assigned Agency POC Name: DOD	Phone and fax #s: (240) 351-8784	

V. COORDINATION (FEMA Use Only)

Type of MA:	☐ Direct Federal Assistance State Cost Share (0%, 10%, 25%)	☐ Technical Assistance State Cost Share (0%)	■ Federal Operations Support State Cost Share (0%)

State Cost Share Percent: 0%	State Cost Share Amount: $0.00	
Fund Citation: 2003-06-3171 EM-9064-XXXX-2501-D	Appropriation code: 58X0104	
Mission Assignment Coordinator (Preparer):	HEIDI MCCOMBS	Date: 02/10/2003
** FEMA Project Officer/Branch Chief (Program Approval):	JOE BEARDEN	Date: 02/10/2003
** Comptroller/Funds Control (Funds Review):	GRINAGER, PAUL E.	Date: 02/10/2003

VI. APPROVAL

State Approving Official (required for DFA and TA):		Date:
** Federal Approving Official (required for all):	M FAIRLEY	Date: 02/10/2003

VII. OBLIGATION (FEMA Use Only)

Mission Assignment #: 3171EM-TX-DOD-06	Amt. This Action: $3,000,000.00	Date/Time Obligated. 02/10/2003
Amendment #: 00	Cumulative Amt. $3,000,000.00	Initials: IFMIS

* Signature required for Direct Federal Assistance and Technical Assistance RFAs.
** Signature required for all RFAs.
FEMA Form 90-129, FEB. 01

Request For Federal Assistance (RFA)

FEDERAL EMERGENCY MANAGEMENT AGENCY REQUEST FOR FEDERAL ASSISTANCE (RFA)	O.M.B. NO. 3067-0278 Expires February 29, 2004

I. TRACKING INFORMATION (FEMA Use Only)

State: Texas (TX)	Action Request #: 50-14291
Program Code/Event #: 3171EM, LOSS OF THE SPACE SHUTTLE COLUMBIA	Date/Time Rec'd: 03/10/2003 19:11

II. ASSISTANCE REQUESTED ☐ See Attached

Assistance Requested: Amend to extend completion date.

Quantity: 1 (Each)	Date/Time Required: 03/10/2003 00:00	Internal Control #: Tracker Task: 50-14064
Deliver Location: Capt Jim Wilkins, 415 South 1st St., Lufkin, TX 75901		
initiator/Requestor Name: John Martin	24-hour Ph/Fax #s: (936) 631-3684	Date: 03/10/2003
POC Name: DOD	24-hour Ph/Fax #s: (240) 351-8784	Date: 03/10/2003
*State Approving Official (Required for DFA and TA):		Date:

III. INITIAL FEDERAL COORDINATION (Operations Section)

Action to:	☐ ESF #: ■ Other:	Date/Time: 3/10/2003 19:11	Priority: ☐ 1 Lifesaving ☐ 2 Life sustaining ☐ 3 High ☐ 4 Medium ■ 5 Normal

IV. DESCRIPTION (Assigned Agency Action Officer) ☐ See Attached

Mission Statement: (Billing instructions are found on www.fema.gov/ofm under the subheading Federal Agencies Doing Business with FEMA.) Urgent, critical recovery of Columbia debris requires immediate establishment of command and control, as well as, operational augment, of the on-going underwater search and recovery effort from the several bodies of water contained within the debris field. In support of USEPA, US Navy Supervisor Salvage & Diving (COMNAVSEA Code 00C, Washington DC) provide command and control of the underwater search and recovery effort, as well as, provision of additional US Navy assets and personnel to augment existing agencies' support. Scope of operations includes search and recovery in two major reservoirs currently identified as containing debris (Toledo Bend and Sam Rayburn), as well as, other local lakes, Ponds, and reservoirs suspected of containing shuttle debris. Navy POC: Capt Chris Murray 703-608-0978, Tom Salmon 703-629-2781. EPA POC: Scott Harris 214-789-9656.

Assigned Agency: DOD	Projected Start Date: 03/10/2003	Projected End Date: 04/30/2003
New or ■ Amendment to MA #: 3171EMTXDOD0600	Total Cost Estimate: $0.00	
Assigned Agency POC Name: DOD	Phone and fax #s: (240) 351-8784	

V. COORDINATION (FEMA Use Only)

Type of MA: ☐ Direct Federal Assistance State Cost Share (0%, 10%, 25%) ☐ Technical Assistance State Cost Share (0%) ■ Federal Operations Support State Cost Share (0%)

State Cost Share Percent: 0%	State Cost Share Amount: $0.00	
Fund Citation: 2003-06-3171EM-9064-XXXX-2501-D	Appropriation code: 58X0104	
Mission Assignment Coordinator (Prepare):	MARSHA BREWER	Date: 03/10/2003
** FEMA Project Officer/Branch Chief (Program Approval):	JOE BEARDEN	Date: 03/10/2003
** Comptroller/Funds Control (Funds Review):	GRINAGER, PAUL E.	Date: 03/10/2003

VI. APPROVAL

* State Approving Official (required for DFA and TA):		Date:
** Federal Approving Official (required for all):	M FAIRLEY	Date: 03/10/2003

VII. OBLIGATION (FEMA Use Only)

Mission Assignment #: 3171EM-TX-DOD-06	Amt. This Action: $0.00	Date/Time Obligated: 03/11/2003
Amendment #: 01	Cumulative Amt. $3,000,000.00	Initials: IFMIS

* Signature required for Direct Federal Assistance and Technical Assistance RFAs.
** Signature required for all RFAs.
FEMA Form 90-129, FEB. 01

Request For Federal Assistance (RFA)

FEDERAL EMERGENCY MANAGEMENT AGENCY REQUEST FOR FEDERAL ASSISTANCE (RFA)	O.M.B. NO. 3067-0278 Expires February 29, 2004

I. TRACKING INFORMATION (FEMA Use Only)

State: Texas (TX)	Action Request #: 50-14330
Program Code/Event #: 3171EM, LOSS OF THE SPACE SHUTTLE COLUMBIA	Date/Time Recd: 03/17/2003 17:21

II. ASSISTANCE REQUESTED ☐ See Attached

Assistance Requested: Amend to increase funding and extend completion date.

Quantity: 1 (Each)	Date/Time Required: 03/17/2003 00:00	Internal Control #: Tracker Task: 50-14064
Delivery Location: Capt Jim Wilkins, 415 South 1st St., Lufkin TX 75901		
Initiator/Requestor Name: John Martin	24-hour Ph/Fax #s: (936) 631-3684	Date: 03/17/2003
POC Name: DOD	24-hour Ph/Fax #s: (240) 351-8784	Date: 03/17/2003
*State Approving Official (Required for DFA and TA):		Date:

III. INITIAL FEDERAL COORDINATION (Operations Section)

Action to:	☐ **ESF #:** ■ **Other:**	**Date/Time:** 03/17/2003 17:27	**Priority:** ☐ 1 Lifesaving ☐ 2 Life sustaining ☐ 3 High ☐ 4 Medium ■ 5 Normal

IV. DESCRIPTION (Assigned Agency Action Officer) ☐ See Attached

Mission Statement: (Billing instructions are found on www.fema.gov/ofm under the subheading Federal Agencies Doing Business with FEMA.) Urgent, critical recovery of Columbia debris requires immediate establishment of command and control, as well as, operational augment of the on-ongoing underwater search and recovery effort from the several bodies of water contained within the debris field. In support of USEPA, US Navy Supervisor of Salvage & Diving (COMNAVSEA Code 00C, Washington DC) provide command and control of the underwater search and recovery effort, as well as, provision of additional US Navy assets and personnel to augment existing agencies' support Scope of operations includes search and recovery in the two major reservoirs currently identified as containing debris (Toledo Bend and Sam Rayburn), as well as other local lakes, ponds, and reservoirs suspected of containing shuttle debris. Navy POC: Capt Chris Murray 703.608-0978, Tom Salmon 703-625-2781. EPA POC: Scott Harris 214-789-9656.

Assigned Agency: DOD	Projected Start Date: 03/17/2003	Projected End Date: 04/30/2003
☐ New or ■ Amendment to MA #: 3171EMTXDOD0601	Total Cost Estimate: $3,000,000.00	
Assigned Agency POC Name: DOD	Phone and fax #s: (240) 351-8784	

V. COORDINATION (FEMA Use Only)

Type of MA:	☐ Direct Federal Assistance State Cost Share (0%, 10%, 25%)	☐ Technical Assistance State Cost Share (0%)	■ Federal Operations Support State Cost Share (0%)

State Cost Share Percent: 0%	State Cost Share Amount: $0.00
Fund Citation: 2003-06-3171 EM-9064-XXXX-2501-D	Appropriation code: 58X0104

Mission Assignment Coordinator (Preparer):	MARSHA BREWER	Date: 03/17/2003
** FEMA Project Officer/Branch Chief (Program Approval):	JOE BEARDEN	Date: 03/17/2003
** Comptroller/Funds Control (Funds Review):	GRINAGER, PAUL E.	Date: 03/17/2003

VI. APPROVAL

State Approving Official (required for DFA and TA):		Date:
** Federal Approving Official (required for all):	M FAIRLEY	Date: 03/17/2003

VII. OBLIGATION (FEMA Use Only)

Mission Assignment #: 3171EM-TX-DOD-06	Amt. This Action: $3,000,000.00	Date/Time Obligated: 03/17/2003
Amendment #: 02	Cumulative Amt. $6,000,000.00	Initials: IFMIS

* Signature required for Direct Federal Assistance and Technical Assistance RFAs.
** Signature required for all RFAs.
FEMA Form 90-129, FEB. 01

CNO Tasking Msg

```
P 1417502 FEB 03 ZYB PSN 960002M17
FM CNO WASHINGTON DC//N312//
TO RULSSEA/COMNAVSEASYSCOM WASHINGTON DC//00/OOC/OOD/O1//
INFO RUCBCLF/COMLANTFLT NORFOLK VA//N3/N5/N7//
RHBVPAB/COMSECONDFLT
RUCBTFA/COMNAVSURFLANT NORFOLK VA//N3/N02F//
RUCBACM/CDR USJFCOM NORFOLK VA//J3//
RUPEUSA/CDR USNORTHCOM//J3/J4//
RUEADWD/DIRMILSPT DCSOPS WASHINGTON DC//DAMO-ODS//
RUCFAAN/FEMA HQ WASHINGTON DC//ARO/ARO-O/ARO-OM/ARO-OS//
RUCCNOM/COMNAVRESFOR NEW ORLEANS LA//N3/N5//
RHMFIUU/COMNAVRESFOR NEW ORLEANS LA//N3/N5//
RUCBFAC/COMEODGRU TWO
RUERSHA/CDRUSAFIVE AND FT SAM HOUSTON TX//AFKB/AFKB-OP//
RUCBCLF/COMLANTFLT NORFOLK VA//N35/N41/N02P//
BT
UNCLAS
MSGID/GENADMIN/CNO WASHINGTON DC - N312//
SUBJ/NAVSEA SUPPORT SHUTTLE COLUMBIA DISASTER OPS//
REF/A/MSG/COMLANTFLT/132138ZFEB2003//
REF/B/MSG/CDR USJFCOM/132139ZFEB2003//
REF/C/MSG/CDR USNORTHCOM/112255ZFEB2003//
REF/D/DOC/FEMA/lOFEB2003//
NARR/REF A IS COMLANTFLT REQUEST FOR NAVSEA 00C ASSETS IN SUPPORT OF
UNDERWATER SEARCH AND RECOVERY IN STS COLUMBIA DISASTER OPS. REF B
IS USJFCOM DEPLOYMENT ORDER. REF C IS USNORTHCOM REQUEST FOR FORCES.
REF D IS FEMA RFA REQUESTING UNDERWATER SEARCH AND RECOVERY ASSETS.//
POC/POTTS/LCDR/N311C/LOC:WASHINGTON DC
/EMAIL:POTTS.JAMES@CNO.NAVY.SMIL.MIL; TEL: 703-692-1851//
RMKS/1. TAKE REF A FORAC. DIRLAUTH. UTILIZE FEMA FUNDING PROVIDED
FOR ASSET SUPPORT.//
BT
```

COMLANTFLT Tasking Msg

```
P 1321382 FEB 03 PSN 951487M34
FM COMLANTFLT NORFOLK VA//N3/NS/N7//
TO RUENAAA/CNO WASHINGTON DC//N312/N511//
RHBPPAB/COMSECONDFLT
RUCBTFA/COMNAVSURFLANT NORFOLK VA//N3/N02F//
RULSSEA/COMNAVSEASYSCOM WASHINGTON DC//00/OOC/OOD/O1//
INFO RHMFISS/CDR USJFCOM NORFOLK VA//J3//
RUCBACM/CDR USJFCOM NORFOLK VA//J3//
RUPEUSA/CDR USNORTHCOM//J3/J4//
RUEADWD/DIRMILSPT DCSOPS WASHINGTON DC//DAMO-ODS//
RUCFAAN/FEMA HQ WASHINGTON DC//ARO/ARO-O/ARO-OM/ARO-OS//
RHMFIUU/COMNAVRESFOR NEW ORLEANS LA//N3/N5//
RUCCNOM/COMNAVRESFOR NEW ORLEANS LA//N3/N5//
RHBPNLT/COMEODGRU TWO
RUERSHA/CDRUSAFIVE AND FT SAM HOUSTON TX//AFKB/AFKB-OP//
RUCBCLF/COMLANTFLT NORFOLK VA//N35/N41/N02P//
BT
UNCLAS //N02300//
OPER/SHUTTLE COLUMBIA DISASTER OPS//
MSGID/ORDER/COMLANTFLT//
REF/A/DOC/FEMA RFA/YMD:20030210//
REF/B/MSG/CDR USNORTHCOM/112255ZFEB2003//
REF/C/MSG/CDR USJFCOM/032139ZFEB2003/-/NOTAL//
REF/D/MSG/CDR USJFCOM/131455ZFEB2003//
REF/E/MSG/CLF/282101ZJAN2002/-/PASEP//
NARR/REF A IS FEMA RFA REQUESTING UNDERWATER SEARCH AND RECOVERY
ASSETS, REF B IS USNORTHCOM REQUEST FOR FORCES TO SUPPORT SPACE
SHUTTLE COLUMBIA OPERATIONS, REF C IS USJFCOM DEPLOYMENT ORDER
SUPPORTING USNORTHCOM IN SPACE SHUTTLE COLUMBIA OPERATIONS, REF D IS
USJFCOM FRAGMENTARY ORDER 1 (ONE) TO REFERENCE C, REF E IS
COMLANTFLT 2002 DISASTER PLANNING ORDER//
ORDTYP/DEPLOYORD/-//
TIMEZONE/Z//
GENTEXT/SITUATION/
1.      SITUATION. SEE REF D.//
        GENTEXT/MISSION/
2.      MISSION. COMLANTFLT DEPLOYS MOBILE DIVING AND SALVAGE
        DETACHMENT WITH APPROPRIATE EQUIPMENT TO SUPPORT USNORTHCOM IN
        SHUTTLE COLUMBIA DISASTER RECOVERY OPERATIONS. THIS DEPLOYMENT IS
        IN COORDINATION WITH NAVSEA-00C UNDERWATER SEARCH AND RECOVERY EFFORT.//
        GENTEXT/EXECUTION/
3.      EXECUTION.
3.A.    CONCEPT OF OPS. ONE MOBILE DIVING AND SALVAGE UNIT
        DETACHMENT DEPLOYS TO VICINITY OF LUFKIN TEXAS WITH APPROPRIATE
        SUPPORT EQUIPMENT TO AUGMENT ONGOING SEARCH AND RECOVERY OPS IN
        WATERS IDENTIFIED TO CONTAIN SHUTTLE DEBRIS COMMENCING ON/ABOUT 13
        FEB.
3.B.    TASKINGS.
3.B.1.  COMSECONDFLT.
3.B.1.(A). DEPLOY ONE MOBILE DIVING AND SALVAGE UNIT DETACHMENT,
        APPROX 20 PERSONNEL AND SUPPORTING EQUIPMENT. COMMENCE DEPLOYMENT
        ON/ABOUT 13 FEB 03.
3.B.1.(B). TRANSFER OPCON OF DET TO CDR USNORTHCOM UPON ARRIVAL TEXAS
           OPERATING SITE.
3.B.1.(C). ACCEPT OPCON OF FORCES FROM CDR USNORTHCOM UPON RETURN TO
           HOMESTATION AND COMPLETION OF SALVAGE MISSION.
3.B.2.  COMNAVSURFLANT. BE PREPARED TO ACCEPT FUNDING FROM NAVSEA FOR O&M
        EXPENDED BY COMEODGRU TWO UNITS SUPPORTING COLUMBIA SHUTTLE RECOVERY
        OPS.
3.C.    TASKING REQUEST.
3.C.1.  CDR USNORTHCOM.
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COMLANTFLT Tasking Msg

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3.C.1.(A).   REQUEST CDR USNORTHCOM ACCEPT OPCON OF MOBILE DIVING AND SALVAGE
             DET UPON ARRIVAL TEXAS OPERATING SITE.
3.C.1.(B).   REQUEST CDR USNORTHCOM TRANSFER OPCON OF MOBILE DIVING AND SALVAGE
             DET TO COMSECONDFLT UPON RETURN TO HOMESTATION AND COMPLETION OF
             SALVAGE MISSION.
3.C.2.       CNO N312.
3.C.2.(A).   REQUEST DEPLOY NAVSEA-00C UNDERWATER SEARCH AND RECOVERY TEAM FOR
             COMMAND AND CONTROL OF UNDERWATER SEARCH AND RECOVERY EFFORT,
             COORDINATING WITH DCO AND MDSU DET DIVE OPS.
3.C.2.(B).   REQUEST DIRECT NAVSEA-00C COORDINATE SALVAGE CONTRACTING TASKS
             SUPPORTING COLUMBIA SHUTTLE RECOVERY OPS.
3.C.2.(C).   REQUEST DIRECT NAVSEA-00C COORDINATE DISBURSEMENT OF FEMA FUNDS
             SUPPORTING REF A AND ASSOCIATED SALVAGE CONTRACTING EFFORTS.
3.C.2.(D).   REQUEST DIRECT NAVSEA-00C COORDINATE DISBURSEMENT OF FEMA FUNDSTO
             COMNAVSURFLANT SUPPORTING O&M COSTS INCURRED BY MDSU DET.
3.D.         COORDINATING INSTRUCTIONS.
3.D.1.       ORDER EFFECTIVE UPON RECEIPT.
3.D.2.       ANTICIPATED DURATION OF OPS 30 DAYS.
3.D.3.       TRANSFER OPCON OF FORCES TO USNORTHCOM AND CONTACT DEFENSE
             COORDINATING OFFICER (DCO) UPON ARRIVAL OF FORCES IN OPERATING
             AREA.
3.D.4.       ACCEPT OPCON FROM USNORTHCOM UPON ARRIVAL HOMESTATION AND
             COMPLETION OF FEMA SUPPORT MISSION.
3.D.5.       DIRLAUTH ALCON. KEEP COMLANTFLT INFORMED.//GENTEXT/ADMIN AND LOG/
             FISCAL GUIDANCE. SEE REF E.//GENTEXT/COMMAND AND SIGNAL/
5.           COMMAND RELATIONSHIPS.
5.A.         FEMA IS THE LEAD FEDERAL AGENCY.
5.B.         USNORTHCOM IS THE SUPPORTED COMMANDER. RESPONSE TASK FORCE (RTF)
             COLUMBIA IS THE SUPPORTED RTF.
6.           SIGNAL.
6.A.         FEMA POC MR. JOHN MARTIN,EPA, FOSC AT BANK OF AMERICA, 2ND FLOOR,
             EPA, LUFKIN TX, FEMA DPO TEL # (214)789-9656.
6.B.         USNORTHCOM POC IS CAPT D. JACKSON, CHIEF CURRENT OPERATIONS AT
             DSN 268-2701(COM (719)474-2701).
6.C.         DEFENSE COORDINATING OFFICER COL AL DOCHNAL (936)630-3115.
6.D.         NAVSEA POC IN OPS AREA CAPT CHRIS MURRAY (202)431-8189.
6.E.         COMLANTFLT POC MR E.D.SHAFFER, N35, (757)836-5591, OR
             CAPT J. TULLEY (757)836-0784.
6.F.         PER ADVICE OF DCO, NO NAVY EPLO REQUIRED ON SITE. LOCAL NAVY
             COORDINATION TO BE HANDLED BY NAVSEA WITH ADDITIONAL SUPPORT FROM
             NAVY REGIONAL PLANNING AGENT POC, MR R.P.DAVIS (504)678-5075.
7.           SITREPS. DUE TO CLF NLT 2100Z. DATA EFFECTIVE 1900Z. INFO CHAIN
             OF COMMAND AND ADD COMNAVRESFOR AS REGIONAL PLANNING AGENT ON
             SITREP.//
             AKNLDG/-//
             BT
```

NAVSEA SITREP Dated 12 April 2003

```
P 121900Z APR 03 ZYB PSN 529147M28
FM COMNAVSEASYSCOM WASHINGTON DC//00C//
TO RUENAAA/CNO WASHINGTON DC//N312//
INFO RUCBCLF/COMLANTFLT NORFOLK VA//N35/N354A/N41/N02P/N3/N5/N7//
RHBPPAB/COMSECONDFLT
RUCBTFA/COMNAVSURFLANT NORFOLK VA//N3/N02F//
RUCBACM/CDR USJFCOM NORFOLK VA//J3//
RHMFIUU/CDR USJFCOM NORFOLK VA//J3//
RUPEUSA/CDR USNORTHCOM//J3/J4//
RUEADWD/DIRMILSPT DCSOPS WASHINGTON DC//DAMO-ODS//
RUCFAAN/FEMA HQ WASHINGTON DC//ARO/ARO-0/ARO-OM/ARO-OS//
RULSSEA/COMNAVSEASYSCOM WASHINGTON DC//00/00C/OOD/01//
RHMFIUU/COMNAVRESFOR NEW ORLEANS LA//N3/N5//
RUCCNOM/COMNAVRESFOR NEW ORLEANS LA//N3/N5//
RHBPNLT/COMEODGRU TWO
RUBDPLA/CDRUSAFIVE AND FT SAM HOUSTON TX//AFKB/AFKB-OP//
RUCOADS/EODMU TEN
RUBDPLA/EODTEU TWO
RHBPJZH/MOBDIVSALU TWO
BT
UNCLAS //N03120//
OPER/COLUMBIA SHUTTLE DISASTER//
MSGID/SITREP/NAVSEA 00C/057/MAR//
REF/A/ORDER/CNO WASHINGTON DC/141750ZFEB03//
REF/B/ORDER/COMLANTFLT/13138ZFEB03//
REF/C/ORDER/COMSECONDFLT/132305ZFEB03//
NARR/REF A IS CNO FRAGORD. REF B IS CLF FRAGORD. REF C IS C2F
FRAGORD FOR SUPPORT OF COLUMBIA SHUTTLE DISASTER.//
POC/NAVSEA SUPSALV/OSC/WILKINS/CAPT/LOC:LUFKIN, TX/
TEL:(703) 395-1639//
POC/NAVSEA SUPSALV/MURRAY/CAPT/LOC:TOLEDO BEND RESERVOIR/
TEL:(409) 579-2920//
POC/MDSU TWO DET BRAVO/RIENDEAU/CW02/LOC:TOLEDO BEND RESERVOIR/
TEL:(409) 579-2918//
PERIOD/111200L/T0:121200L/ASOF:121300L//
HEADING/OWN SITUATION//
5UNIT
/UNITDES           /UNITLOC              /CMNTS
//NAVSEA OOC//
//CTE 20.14.4.2    /MDSU TWO DET BRAVO//
GENTEXT/SITUATION/NAVSEA 00C AND MDSU-2 SALVAGE DETACHMENT DEPLOYED
TO LUFKIN, TX ISO COLUMBIA SHUTTLE DISASTER//
GENTEXT/OPERATIONS/RECOVERY OF DEBRIS WITHIN TOLEDO BEND RESERVOIR,
LAKE NACOGDOCHES AND OTHER LOCAL BODIES OF WATER AS DIRECTED BY
EPA/NASA.
STATISTICAL DATA:
CRITICAL EQUIPMENT LOCATION:
 TRCS             ON SITE
 LWDS             ON SITE
 NAVY:
 NAVY DAILY DIVE TOTALS:      38
 DEPTH/WATER TEMP/AIR TEMP:   75 FT/50 F/77 F
 BOTTOM TYPE/VIS/CURRENT:     MUD/0-3 FT/0.0-0.2 KTS
 TOTAL BOTTOM TIMES:          7 HRS 34 MINS
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NAVSEA SITREP Dated 12 April 2003

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TOTAL TIME OF DIVES:     8 HRS 40 MINS
RIG:                   SCUBA/SURFACE SUPPLIED
DEPLOYMENT DIVE TOTALS:  1334
DEPLOYMENT TBT:          320 HRS 04 MINS
DEPLOYMENT TTD:          349 HRS 30 MINS
SEARCH ASSETS IN TOLEDO BEND RESERVOIR:
SUPSALV (5)
CIVILIAN DIVE AND SUPPORT ASSETS:
HOUSTON POLICE DEPARTMENT
DEPARTMENT OF PUBLIC SAFETY
USCG AUXILIARY
LOUISIANA FISH AND WILDLIFE
TEXAS PARKS AND WILDLIFE
EPA
JASPER COUNTY EMERGENCY CORP
SABINE RIVER AUTHORITY//
GENTEXT/PERSONNEL/
NAVSEA SUPSALV                  03
MDSU2                           16
RESERVE DET                     02
SUPSALV CONTRACTOR              11//
GENTEXT/SIGNIFICANT EVENTS/TWO CIVILIAN DIVE TEAMS DEPART 11 APR
PM. SEARCH ASSETS (2 MULTI-BEAMS AND 4 SIDE SCANS) COMPLETE
REMAINING HIGH PRIORITY AREAS AND BEGIN DEMOBILIZATION. DIVE TEAMS
(2 NAVY AND 1 CIVILIAN) CLEAR LAST 25 TARGETS WITH NEGATIVE
RESULTS. ALL ASSETS EXPECTED TO COMPLETED DEMOBILIZATION AND IN
TRANSIT TO PARENT COMMANDS BY 14 APR AM.
TOLEDO BEND DATA:
TOTAL       SEARCH AREA        14.69 SQ.NM
TOTAL       AREA SEARCHED      14.69 SQ.NM
TOTAL       TARGETS ACQUIRED    2709
TOTAL       CLEARED TARGETS     2709
DAILY       CLEARED TARGETS     057
LAKE NACOGDOCHES DATA:
TOTAL       SEARCH AREA         3.17 SQ.NM
TOTAL       AREA SEARCHED       3.17 SQ.NM
TOTAL       TARGETS ACQUIRED    365
TOTAL       CLEARED TARGETS     365
DAILY       CLEARED TARGETS     000
GENTEXT/COMMANDERS COMMENTS/WE FOUND LOTS OF ITEMS, BUT MOSTLY JUST
JUNK, FLOTSAM AND JETSAM, LONGAGO SUNK. WE FOUND HOMES, CARS AND
BOATS, AND A MAYTAG MACHINE, BUT COLUMBIA DEBRIS WAS SURPRISINGLY
LEAN. WE'LL REMEMBER THE COLD AND WARM DAYS, AND THE DRENCHING,
THE FRIENDSHIPS, THE FEASTS AND BLOODY BUCKET THIRST QUENCHING,
AS WE CLOSE OUT THIS OP, ALL HAVE GIVEN THEIR BEST; NOW SPACE
SHUTTLE COLUMBIA--WHERE NOT FOUND--IN PEACE REST. ALL SEARCH
AND DIVING OPERATIONS COMPLETED. TREMENDOUS SUPPORT FROM NASA,
FEMA, DOMS AND ALL AGENCIES INVOLVED THROUGHOUT THE OPERATION.
COMBINED DIVING OPERATIONS FROM POLICE, EPA AND NAVY STRENGTHENED
THE TEAM AS A WHOLE AS EACH AGENCY BROUGHT A DIFFERENT PERSPECTIVE,
TRAINING AND EXPERIENCE TO THE OPERATION. FINAL SITREP THIS
OPERATION. MINIMIZE CONSIDERED. SUPSALV SENDS.//
BT
```

APPENDIX D

RESON 8125

AND

8101 DATA SAMPLES

COLUMBIA RECOVERY PROJECT

Prepared by: C&C TECHNOLOGIES, INC.

Reson Bathymetry Statistics

System	Acrosstrack beam width (deg)	Number of beams	Swam Width (m)	Acrosstrack beam spacing at edge of swath (m)	Alongtrack beam spacing (m)
8125	0.50	240	30.60	0.35	0.18
8101	1.50	101	68.80	3.60	0.18

All numbers are for water depth of 10m.

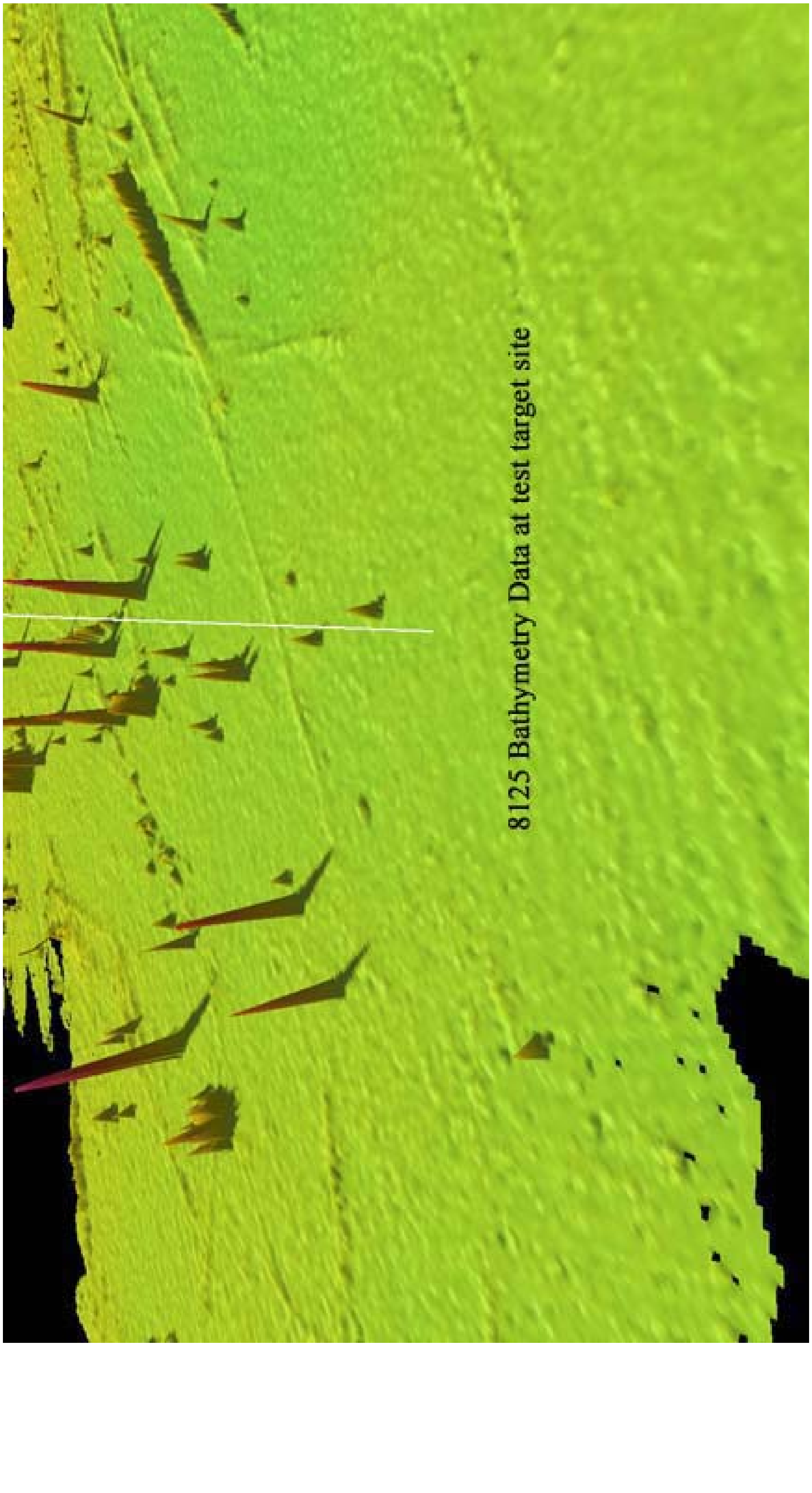
Acrosstrack beam spacing is dependent only on depth and beam width.

Alongtrack beam spacing is dependent on vessel speed and water depth. It should be similar for both systems.

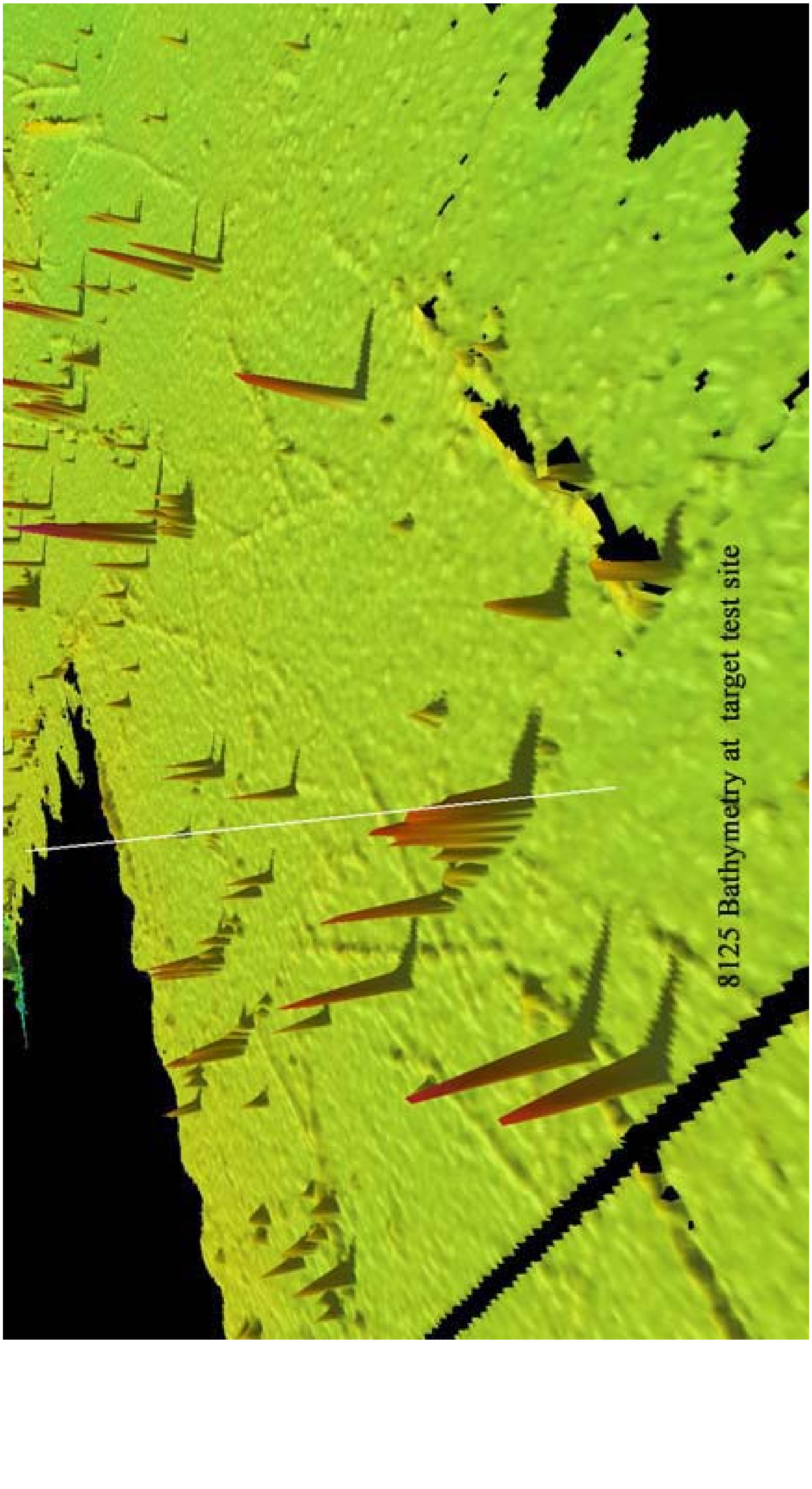
Swath width of 8101 with at most 0.35m acrosstrack beam spacing is about 11.7m with only 50 beams, as compared to the 8125 with 30.6m swath width and 240 beams.

RESON 8125 MULTIBEAM

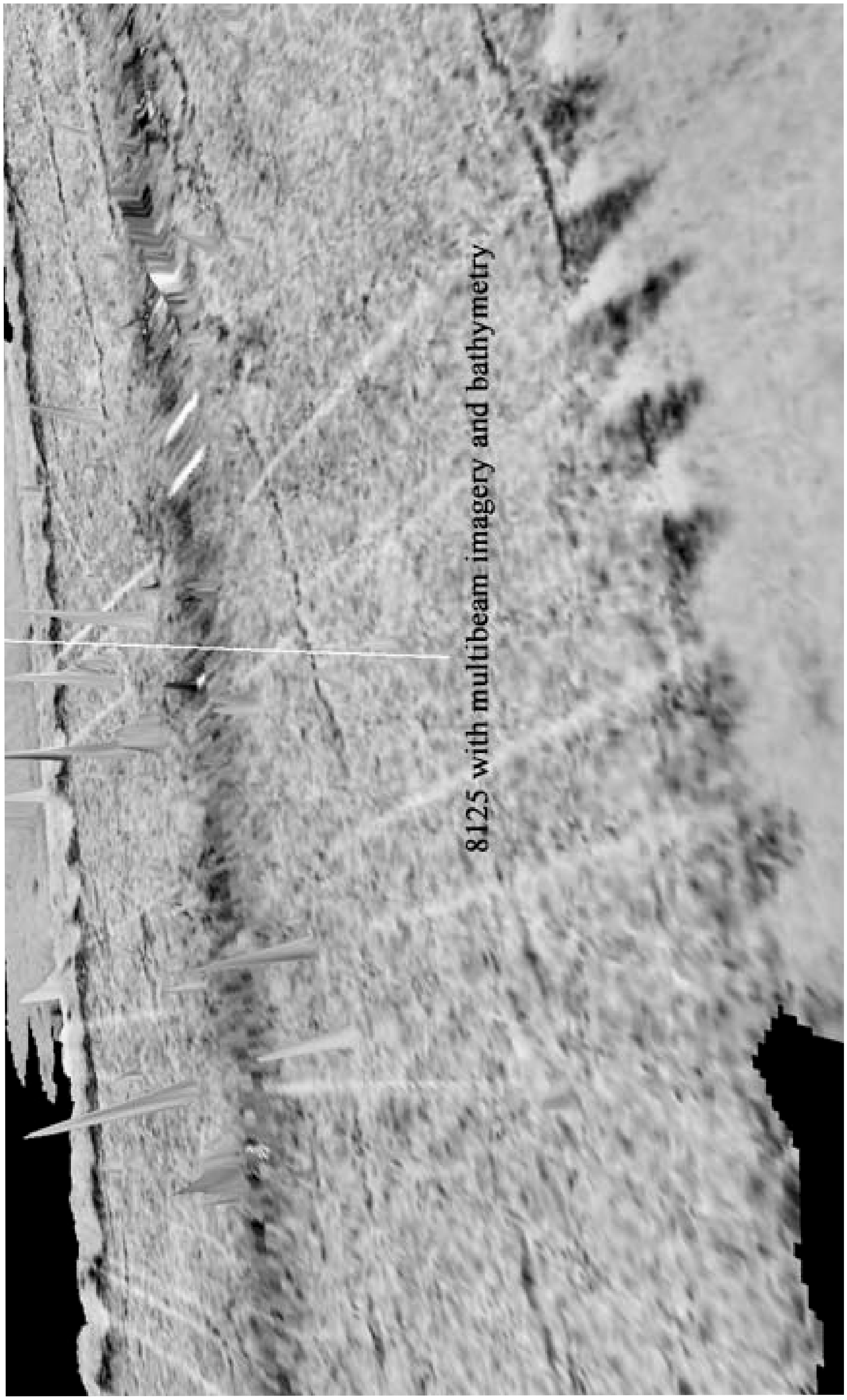
8125 Bathymetry Date at test target site



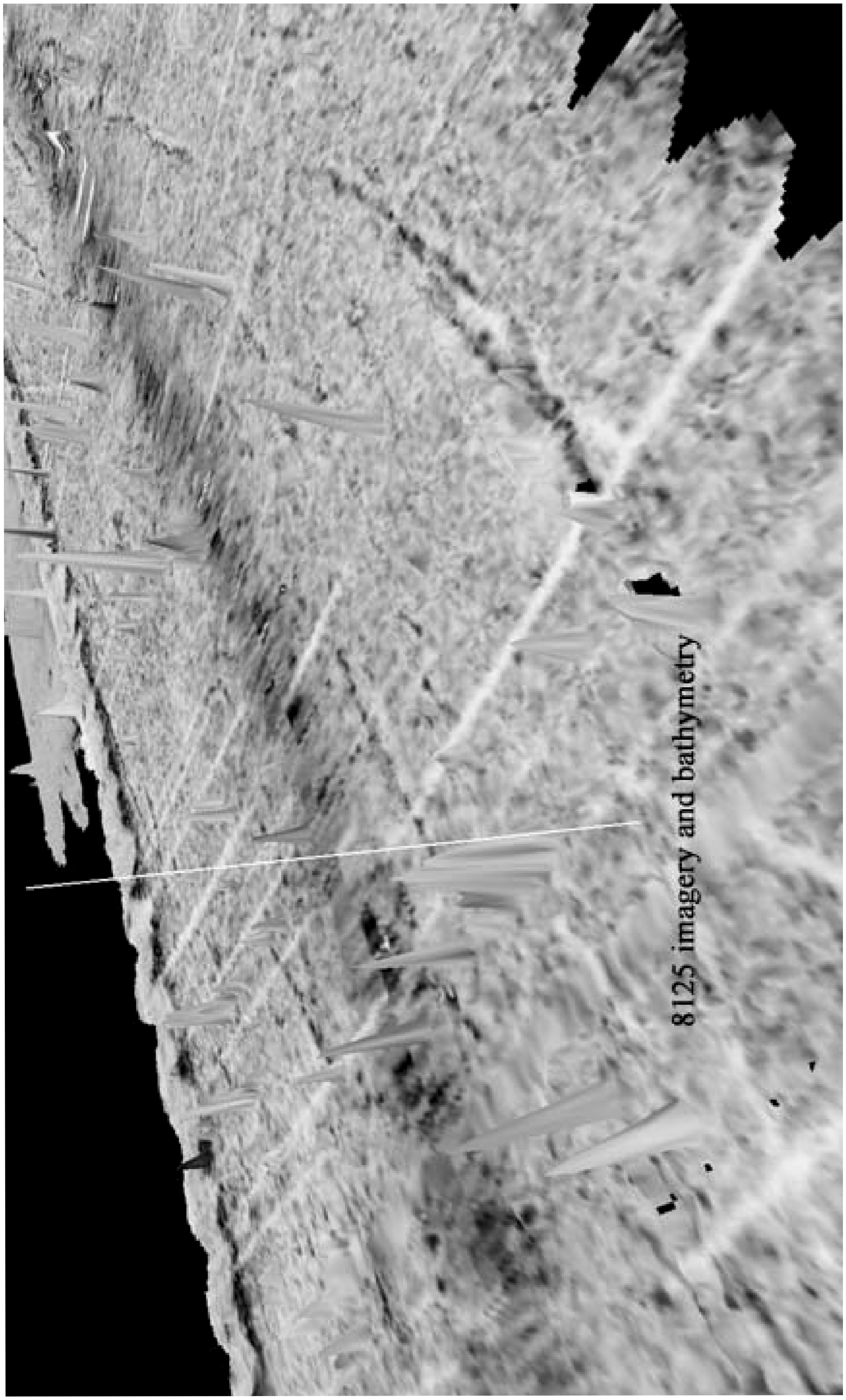
8125 Bathymetry Date at test target site



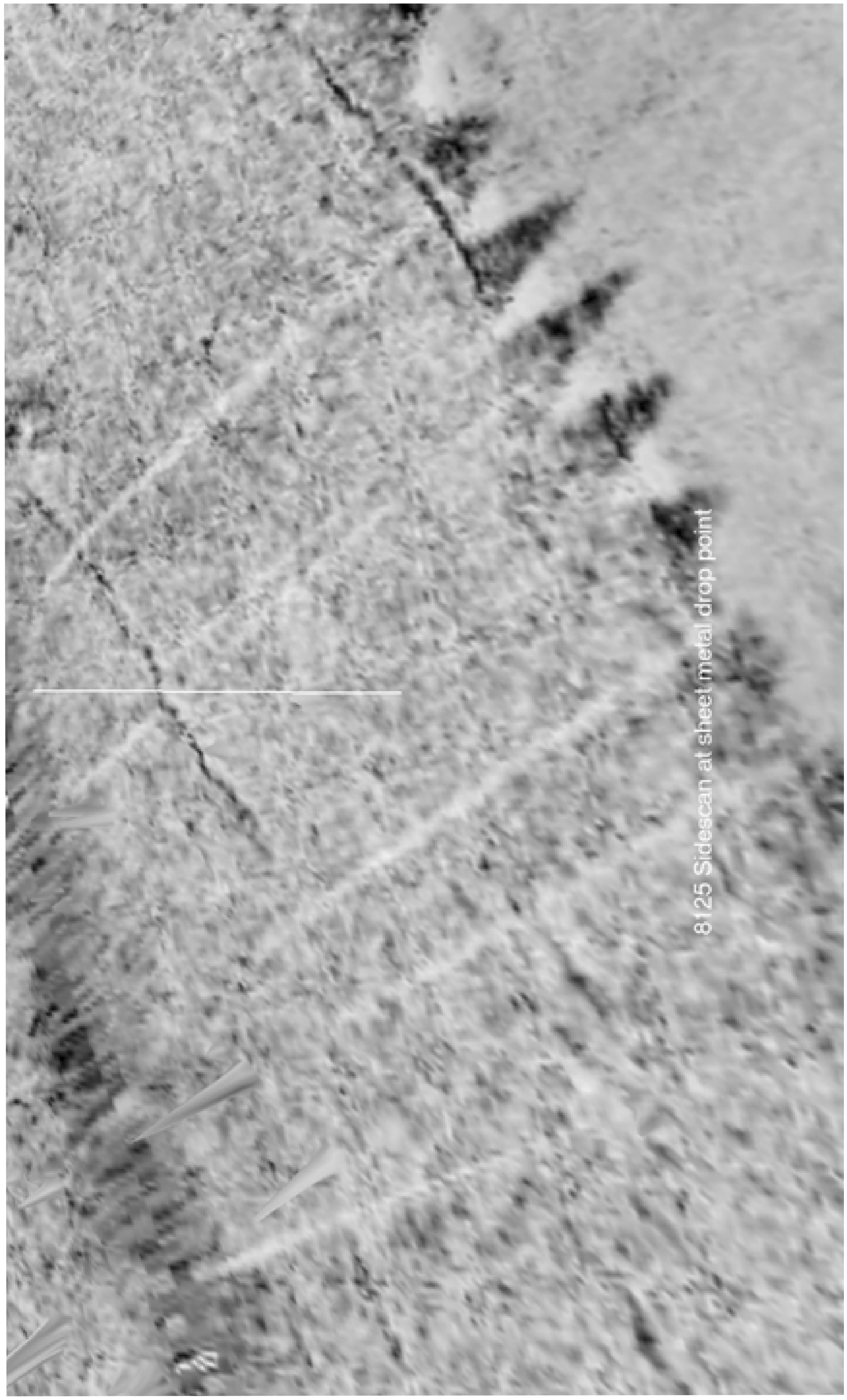
8125 with multibeam imagery and bathymetry



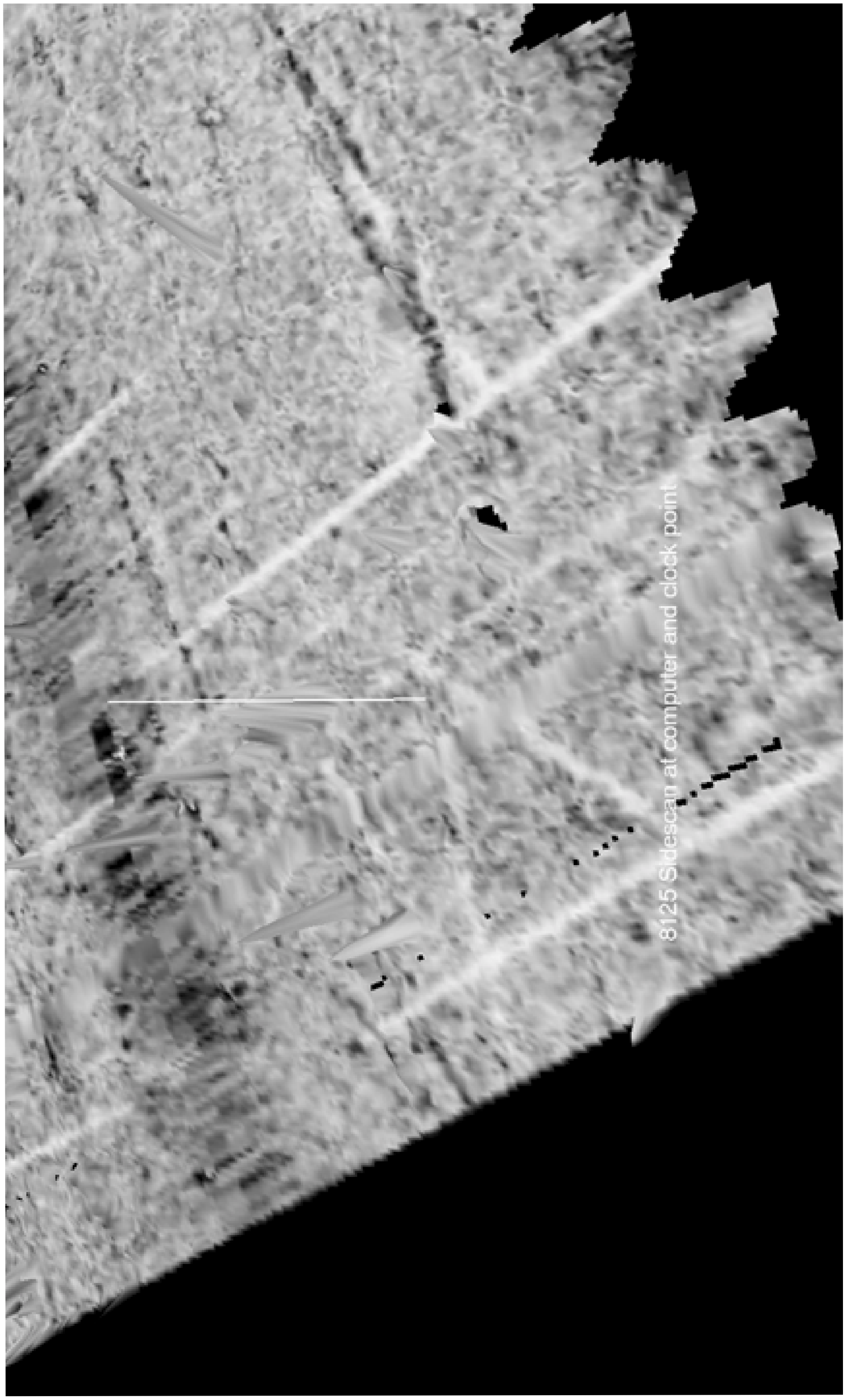
8125 imagery and bathymetry



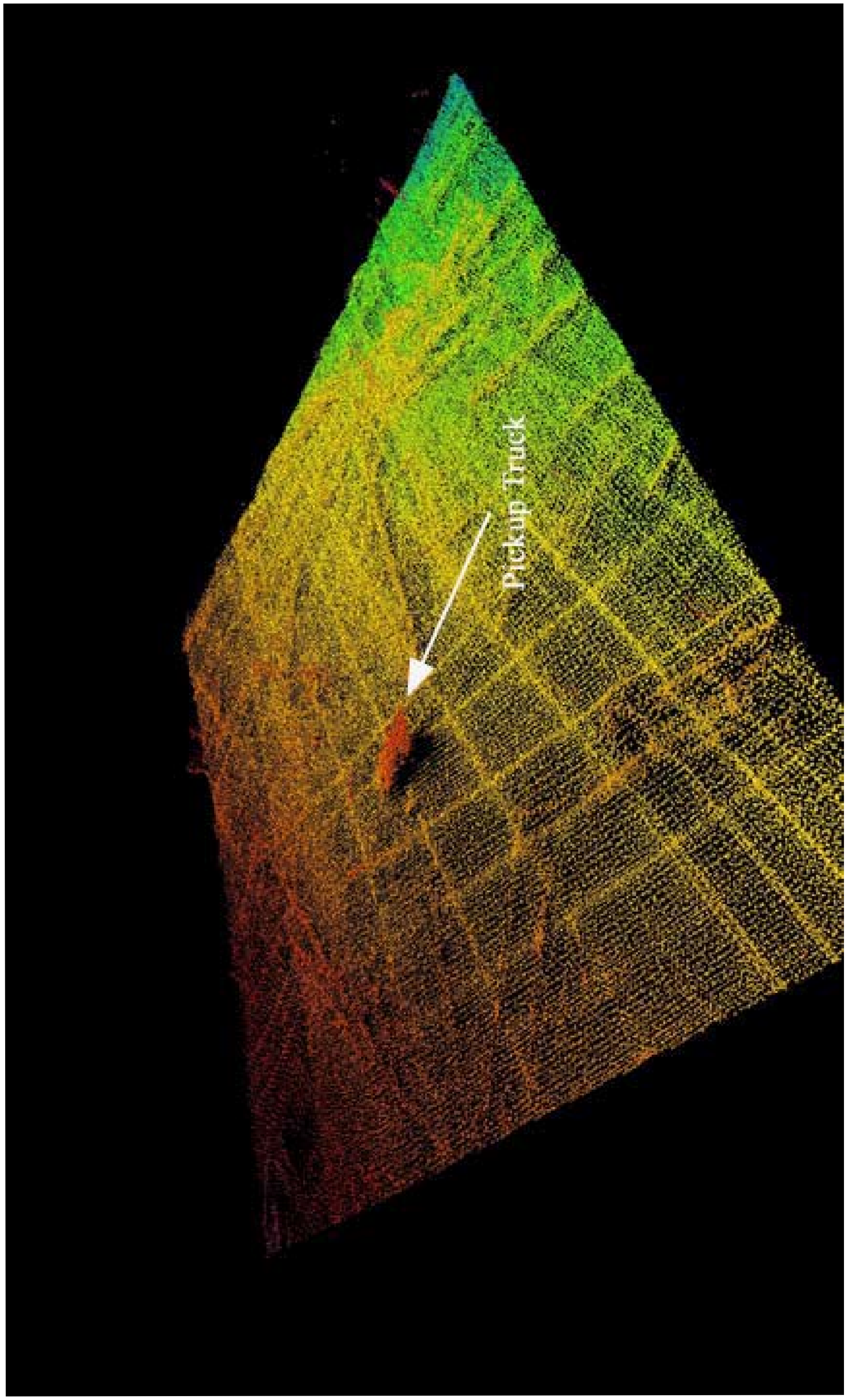
8125 Sidescan at sheet metal drop point



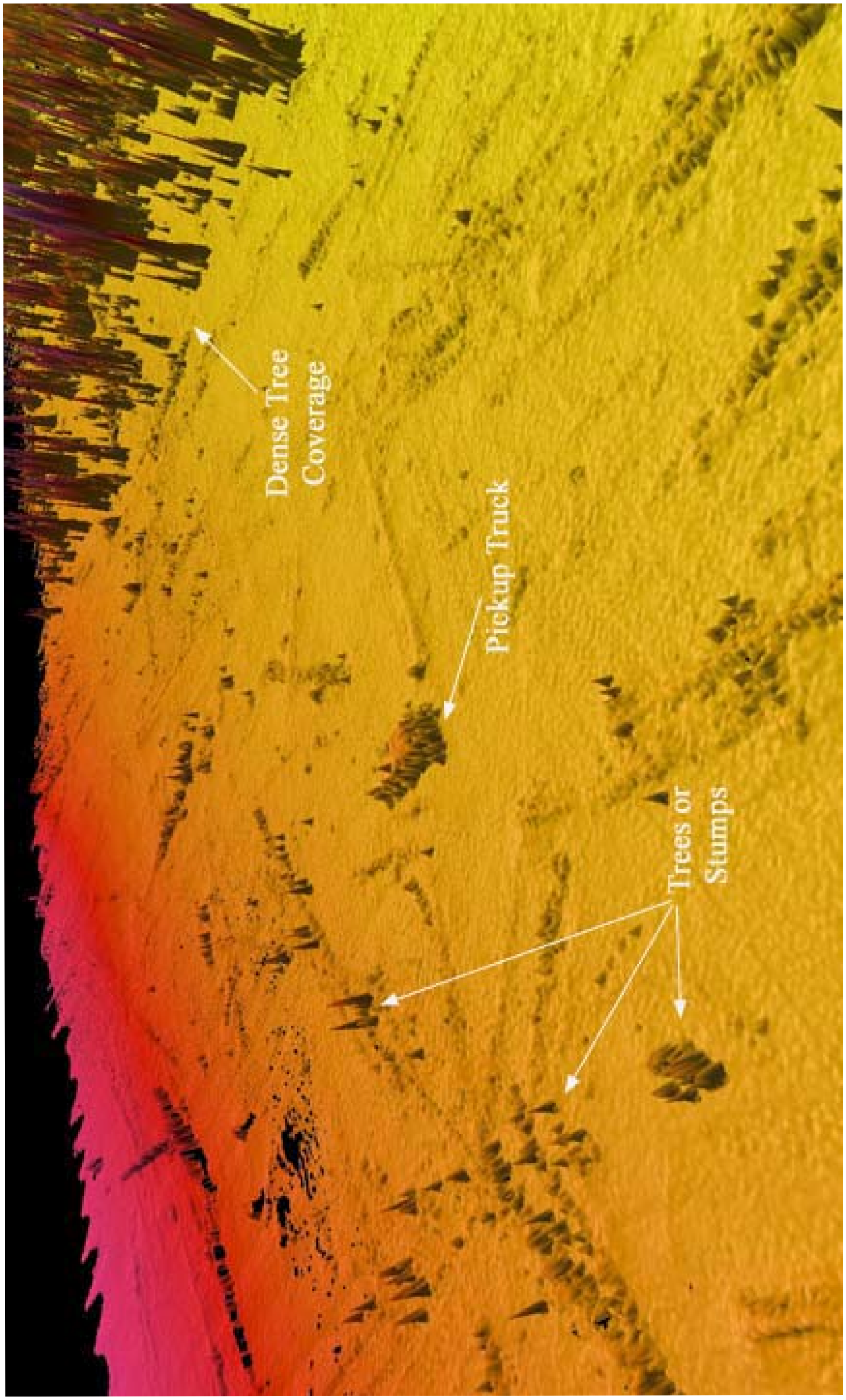
8125 Sidescan at computer and clock point



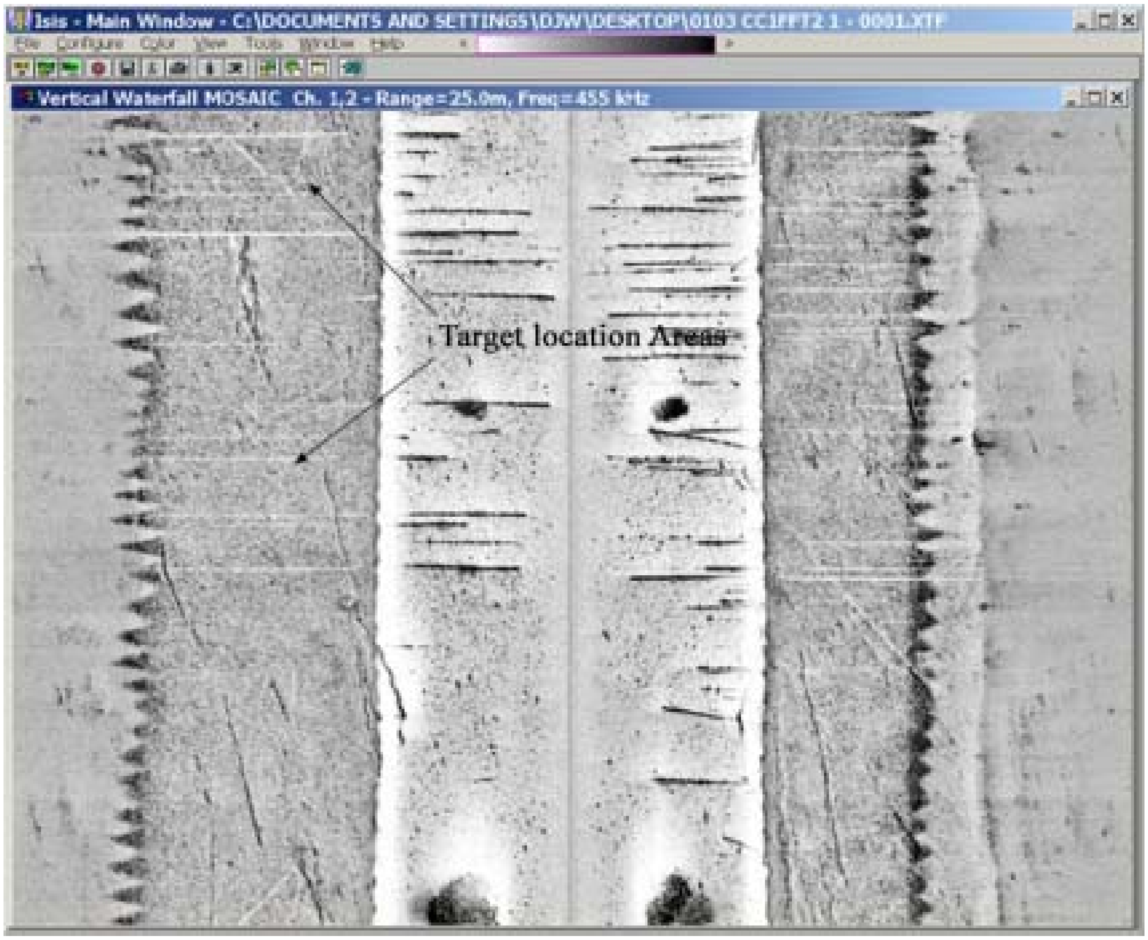
Pickup Truck



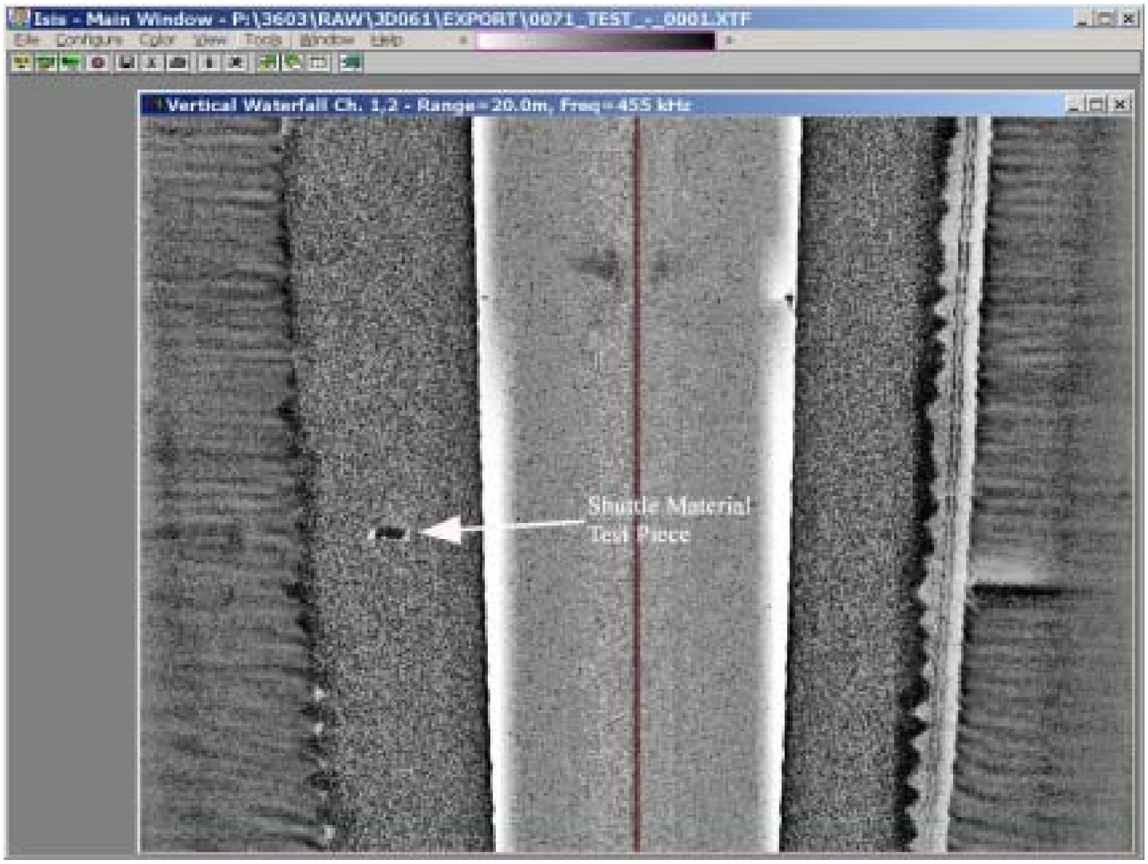
Trees or Stumps/Pickup Truck/Dense Tree Coverage



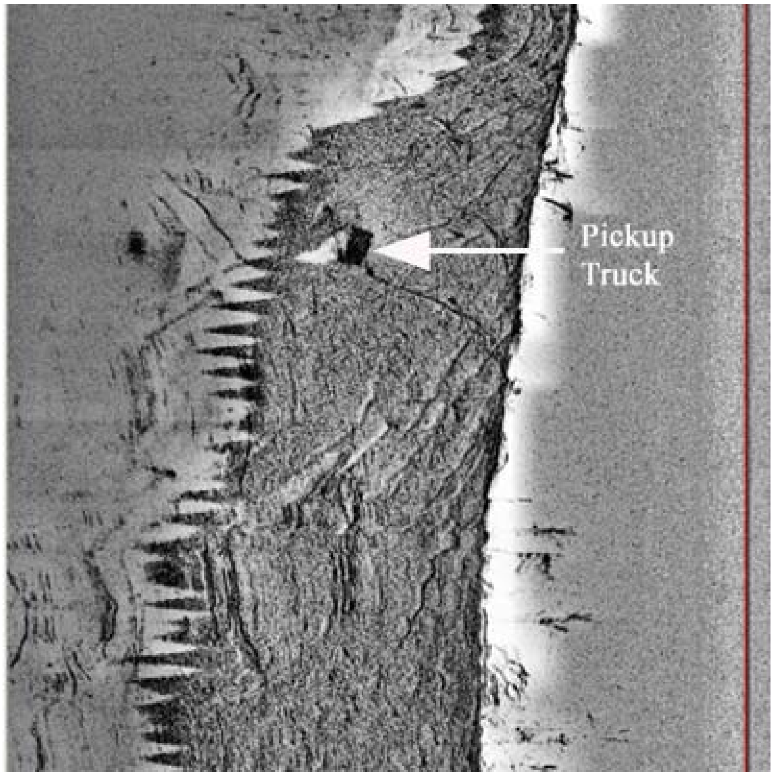
Target Location Areas



Shuttle Material Test Piece

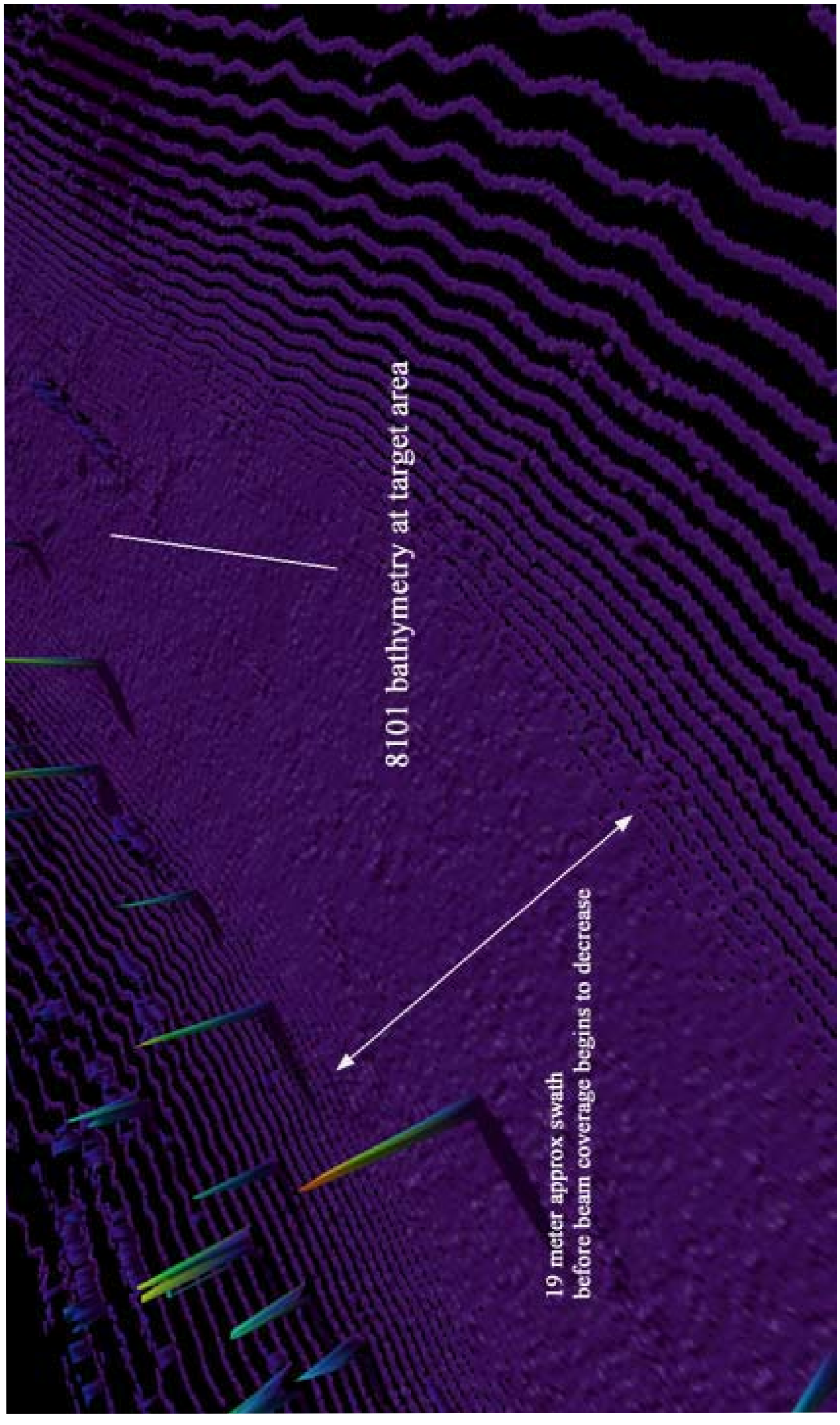


Pickup Truck



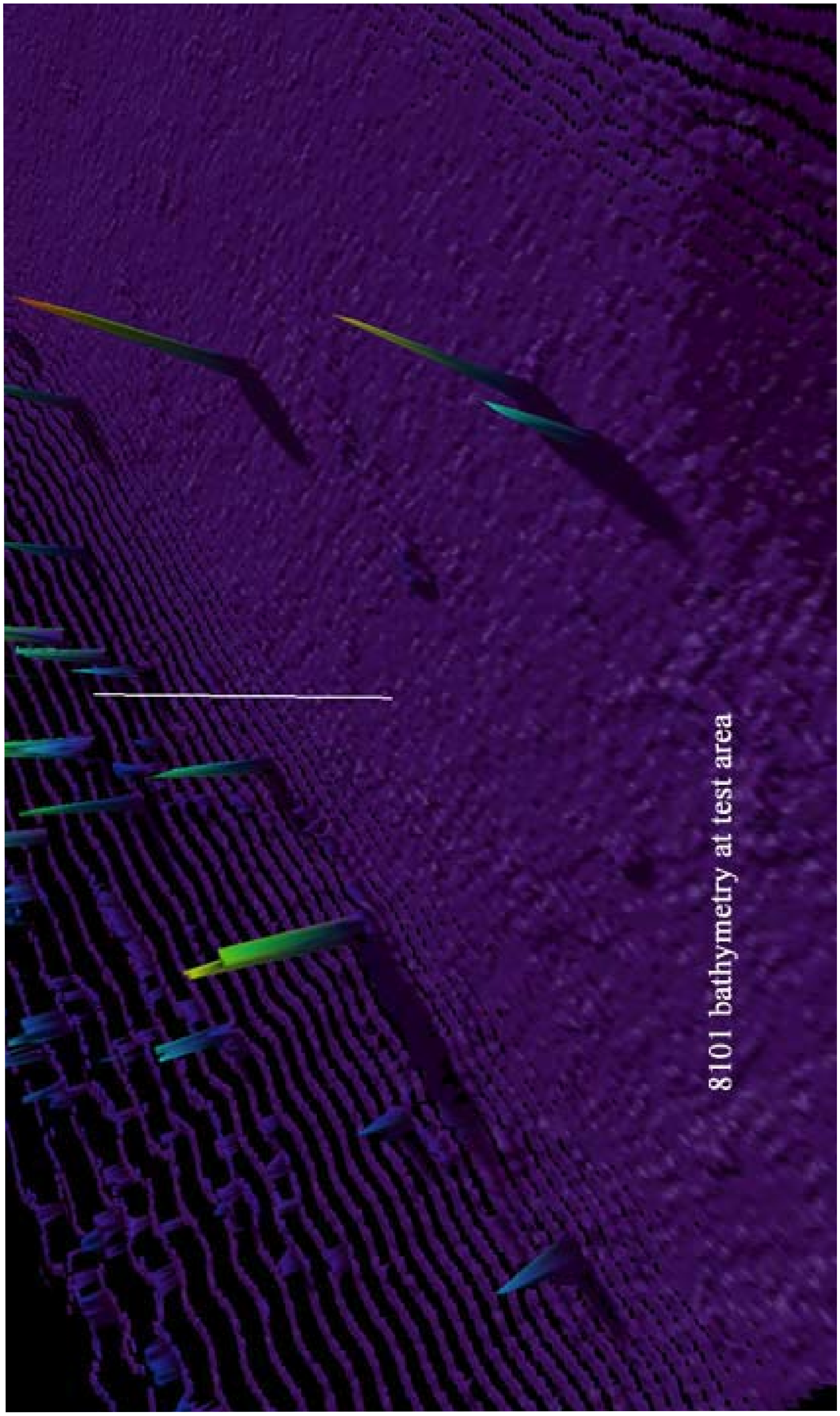
RESON 8101 MULTIBEAM

8101 Bathymetry At Tartet Area/(19 meters approx. swath before beam coverage begins to decrease)

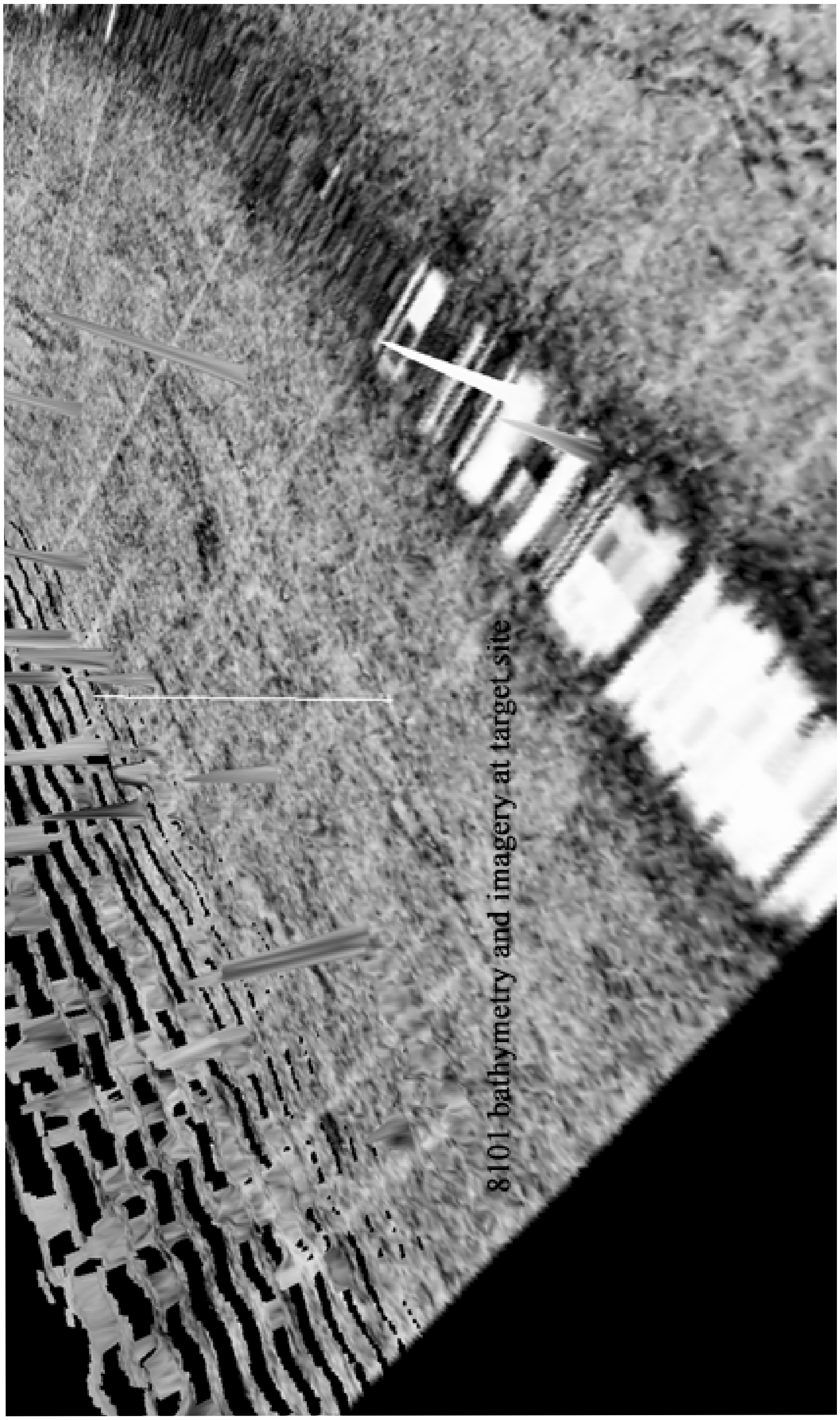


8101 Bathymetry and Imagery At Target Area

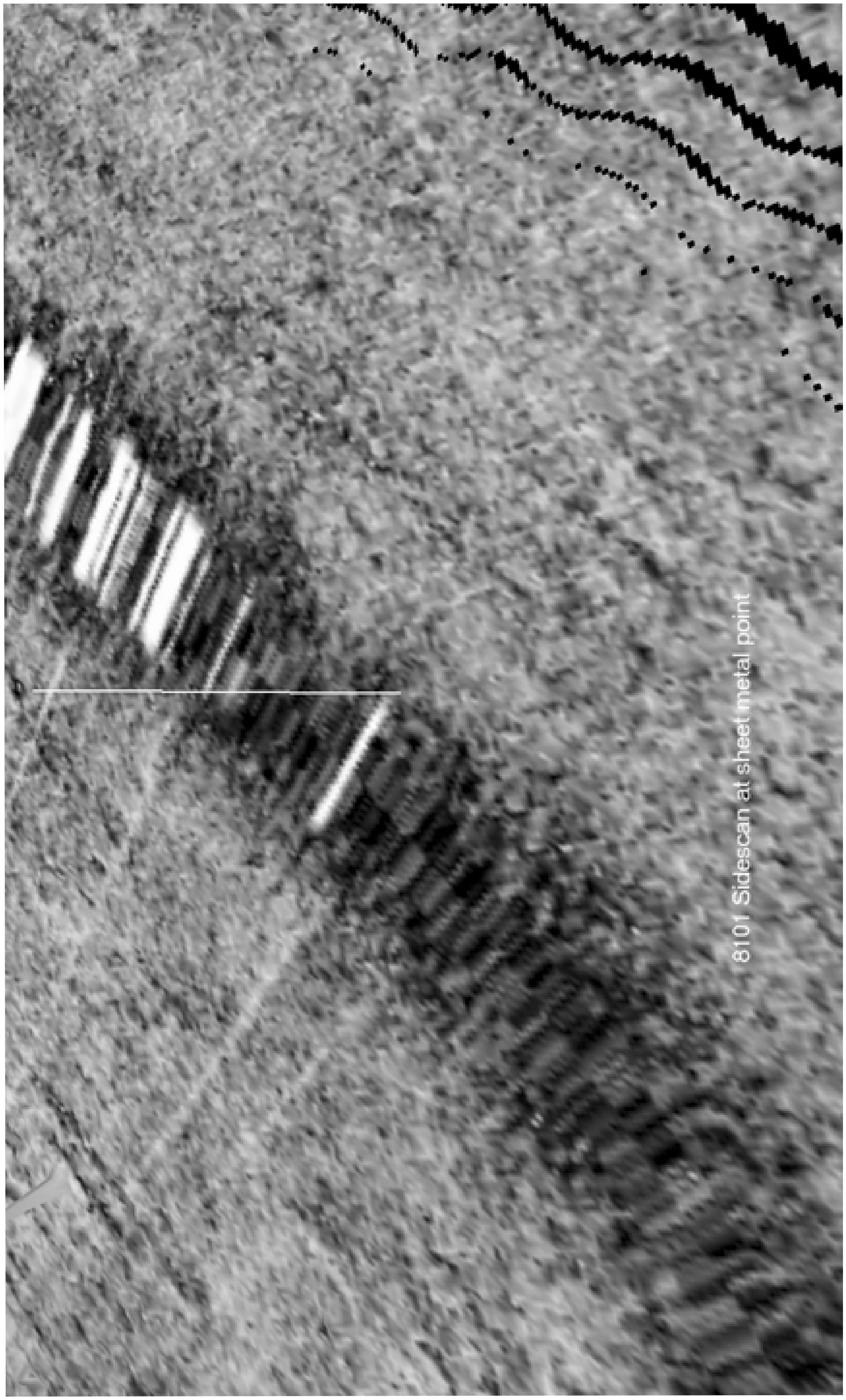
8101 Bathymetry At Test Area



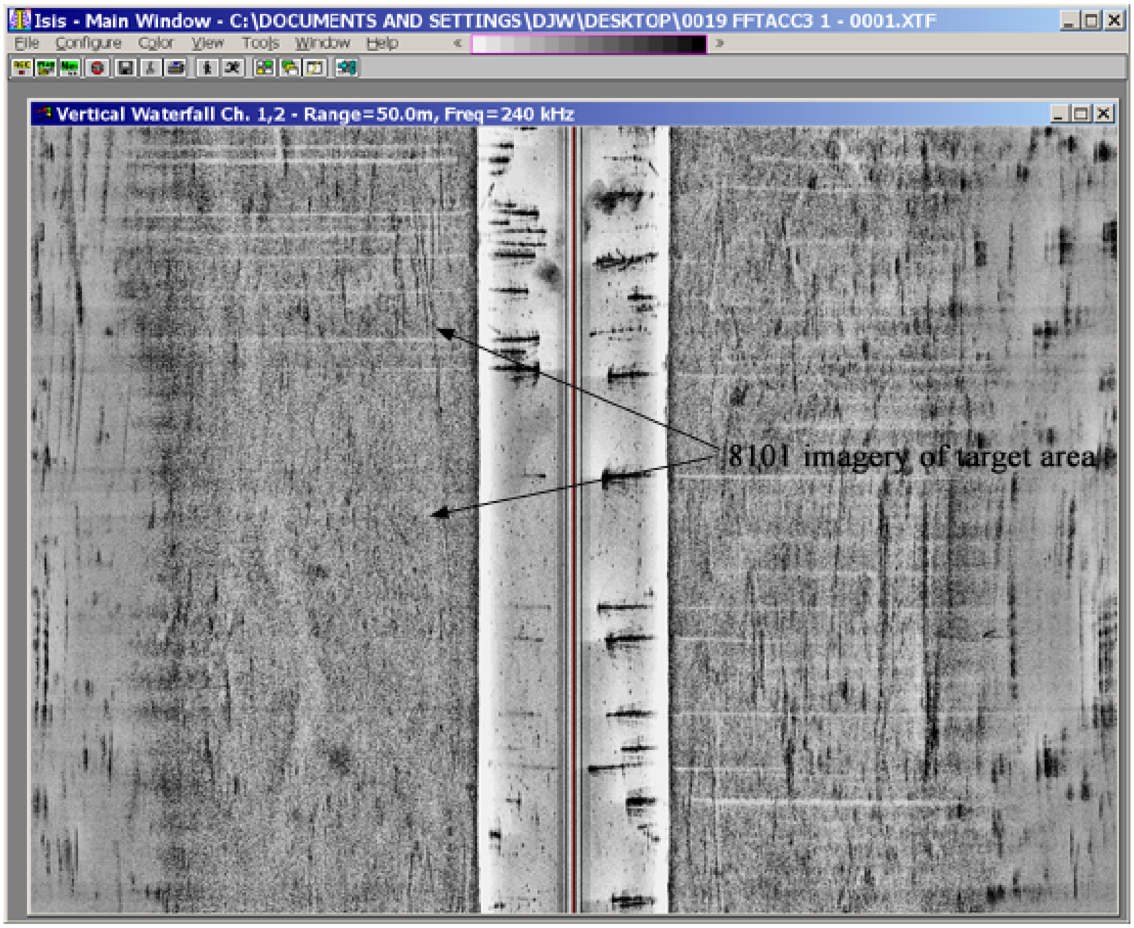
8101 Bathymetry And Imagery At Target Site



8101 Sidescan At Sheetmetal Point



8101 Imagery Of Target Area



UNIVERSITY OF NEW HAMPSHIRE COMBINED UNCERTAINTY AND BATHYMETRY ESTIMATOR (CUBE) ANALYSIS

University of New Hampshire Combined Uncertainty and Bathymetry Estimator (CUBE) Analysis

At the request of Capt. Jim Wilkins, USN, Brian Calder and Larry Mayer of the Center for Coastal and Ocean Mapping, University of New Hampshire, came to the Toledo Bend Reservoir search headquarters to help with the evaluation of current practices aimed at identifying and recovering wreckage from the space shuttle Columbia.

1600 9 March 2003: First call received from Capt. Wilkins. Agreed to look at sample data and see what, if anything, we could do with it and to travel to Toledo Bend Reservoir the following day.

1900 9 March 2003: Sample Reson 8125 data received from Al Couson – C&C technologies via FTP. Data sent in both XTF and XYZ format.

2000-2300 9 March: Mayer explored ways of enhancing small target detection via color map optimization and the use of full point data (PFM class) using FLEDERMAUS.
Calder processed in parallel using CARIS.

1000 10 March 2003: Calder and Mayer depart UNH for Houston
1830 10 March: Arrive Houston
2240 10 March: Arrive Fin and Feather Lodge – Briefing by Capt. Wilkins

0800 11 March: Team meeting to plan day’s activities. Calder and Mayer to evaluate possible approaches for enhancing processing flow and target detection capabilities.

APPROACH TAKEN:

Calder and Mayer focused on developing a multibeam sonar processing protocol that would maximize the chances of identifying small targets in the terribly cluttered environment of the reservoir. The fundamental question facing all of us is whether or not the 8125 can resolve targets the size of an OEX recorder (7.5” x 17” x 22”). If we determine that the sonar can resolve a target of this size (using bathymetry, imagery or both), the next issue is whether we could do anything to maximize the probability of detecting a real target in the context of the complex reservoir floor.

To address the question of target resolution we worked with the 8125 data collected by C&C Technologies over several targets deployed near the Fin and Feather dock. In particular we worked with lines that crossed the position of desktop computer chassis that had been deployed as target close to the size of the OEX recorder.

Several processing steps were taken:

1. Raw soundings from 8125 were gridded at 10 cm spacing, rendered, and sun-illuminated to enhance target identification. 10 cm was chosen because in the water depths of the target deployment (approx 8 – 10 m) the footprint of the 8125 should be approx. 5 – 8 cm in diameter. (Fig 1).

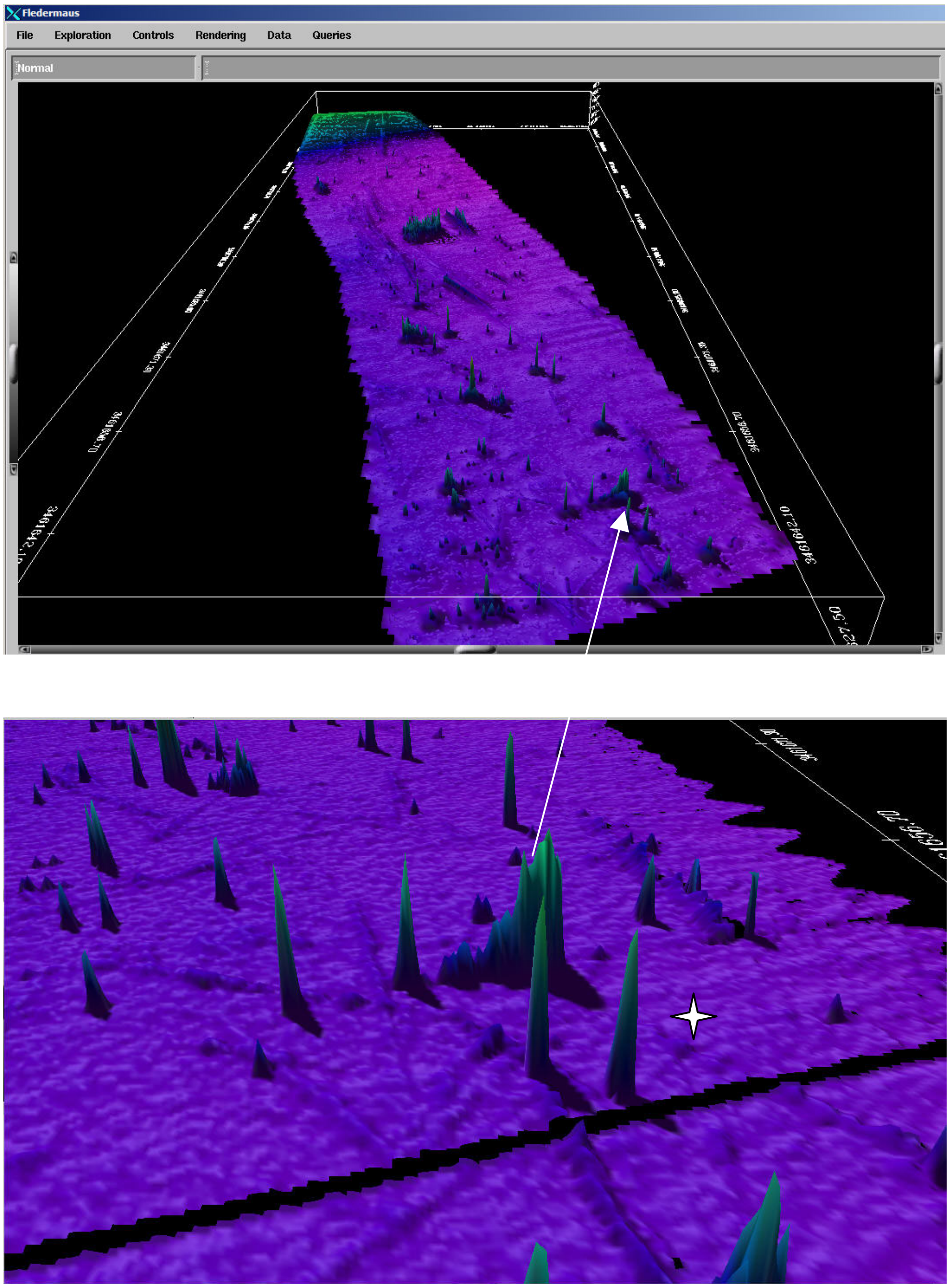


Figure 1 top – Raw data from whole of line 0103 over area where computer chassis was dropped.

bottom – close up of southern part of line in region where chassis was dropped – feature under star is 40 cm high and 50 cm across.

As is clear in Fig. 1 there are a number of large features in the bathymetry some of which may be real features (trees) and others which may be system noise or other midwater targets (fish). These targets dominate the view. Most of the targets that we are interested in would not reach high into the water column so one quick approach to focusing on smaller targets is to cut the data at some height above the seafloor and stretch the color map to accentuate those features that are in the depth range of interest (Fig 2).

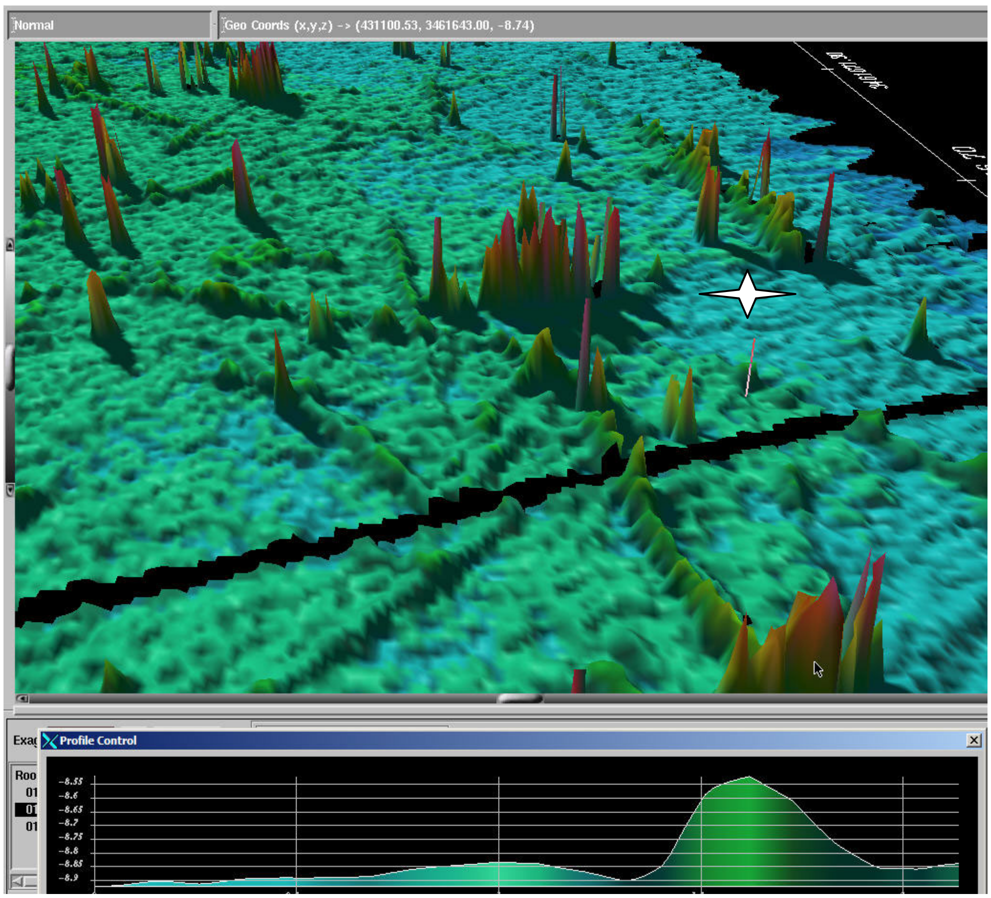


Figure 2. Same scene as above with color mapped stretch to accentuate smaller targets. Profile across 40 cm high target in Fig 1 is at bottom of Figure 2

2. Even with the enhanced color map, the clutter caused by larger targets dominates the image. Calder therefore modified his CUBE (Combined Uncertainty and Bathymetry Estimator) algorithm to attempt to remove the large-feature clutter (as well as soundings deemed to be outliers by the algorithm). The result of the CUBE processing is shown in Figure 3.

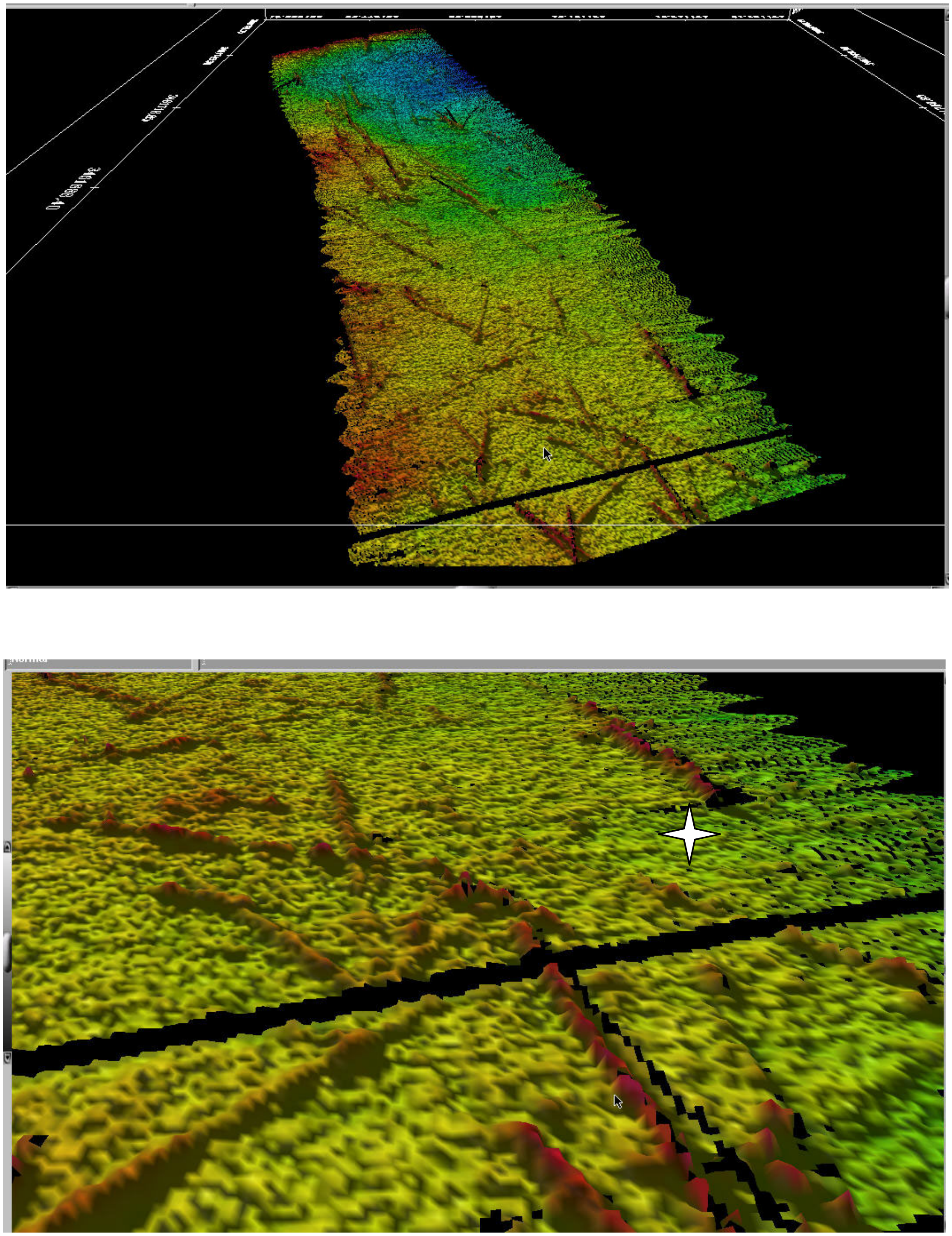


Figure 3. Output of CUBE algorithm combined with color map enhancement. Note how CUBE has removed all of high-standing (> 2 m above lakefloor) objects thus allow focusing on smaller targets. 40 cm object is more clearly visible now.

3. In an effort to see if the backscatter from the 8125 could further enhance target discrimination, Eric Maillard from Reson generated a GEOTIFF image of the backscatter from the 8125 for the same line. This image was then texture mapped on the bathymetry (Figure 4).

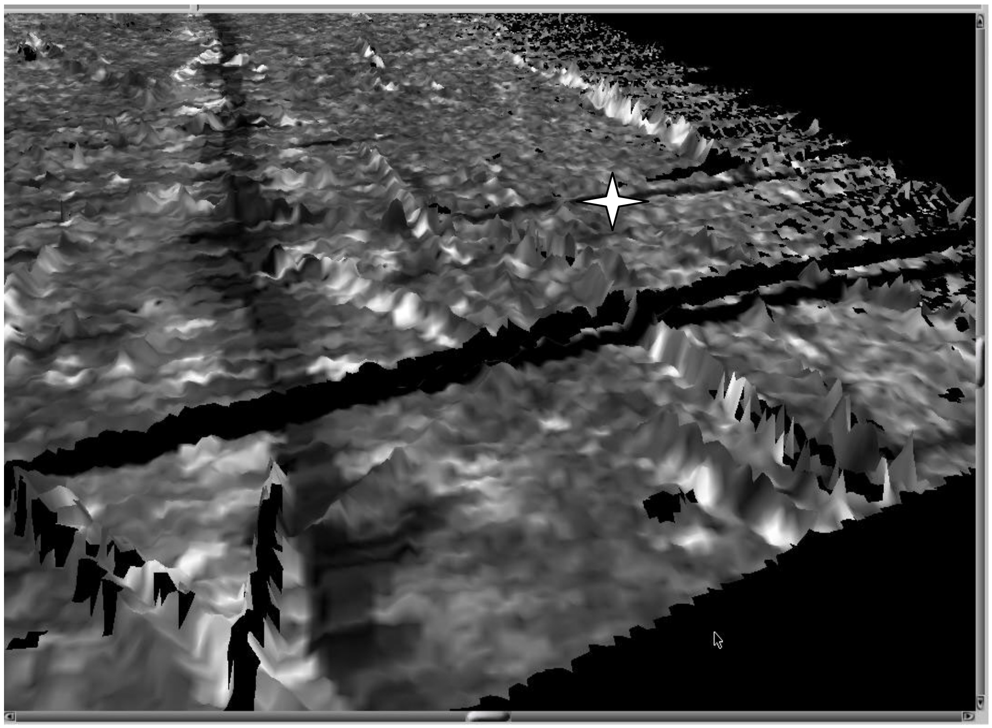
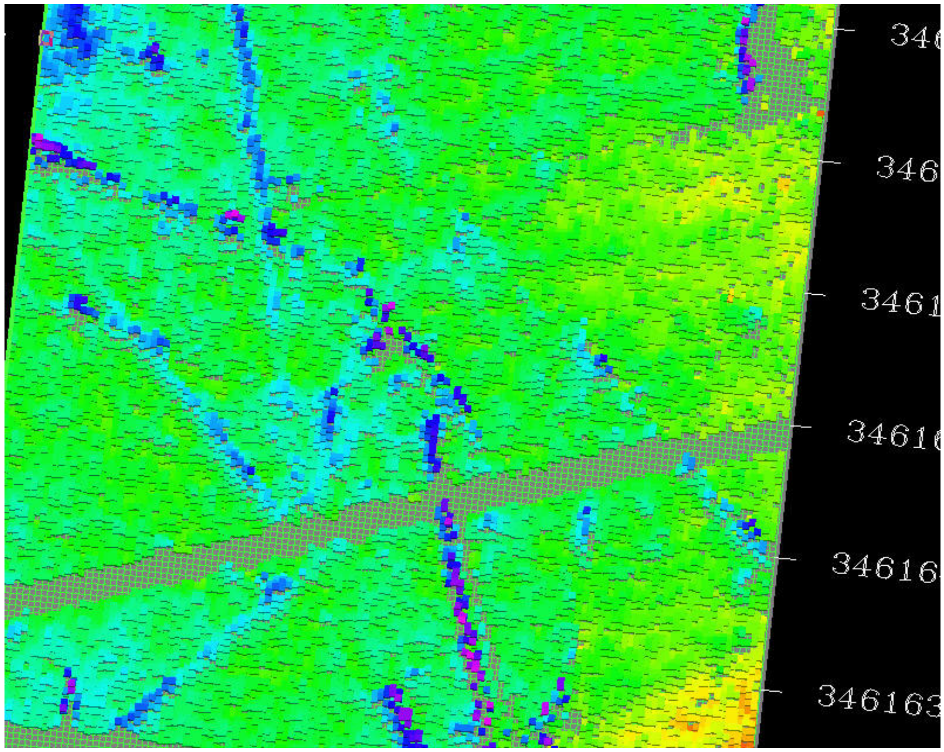


Figure 4. Reson 8125 backscatter draped on bathymetry. High backscatter is lighter color. 40 cm target we have been looking at (under star) shows low backscatter implying it is probably not metal object but until test calibrations are run, backscatter response of targets is not known.

4. Each of the previous views of the lakefloor are the result of a rendering process that drapes a surface over the selected points. While such a display provides excellent general context for the shape of the lakefloor it can sometimes distort the shape of small objects. In an attempt to resolve the shape of small objects with the finest possible resolution, we have extracted the individual soundings and displayed them in both 2 and 3-D (Figure 5).



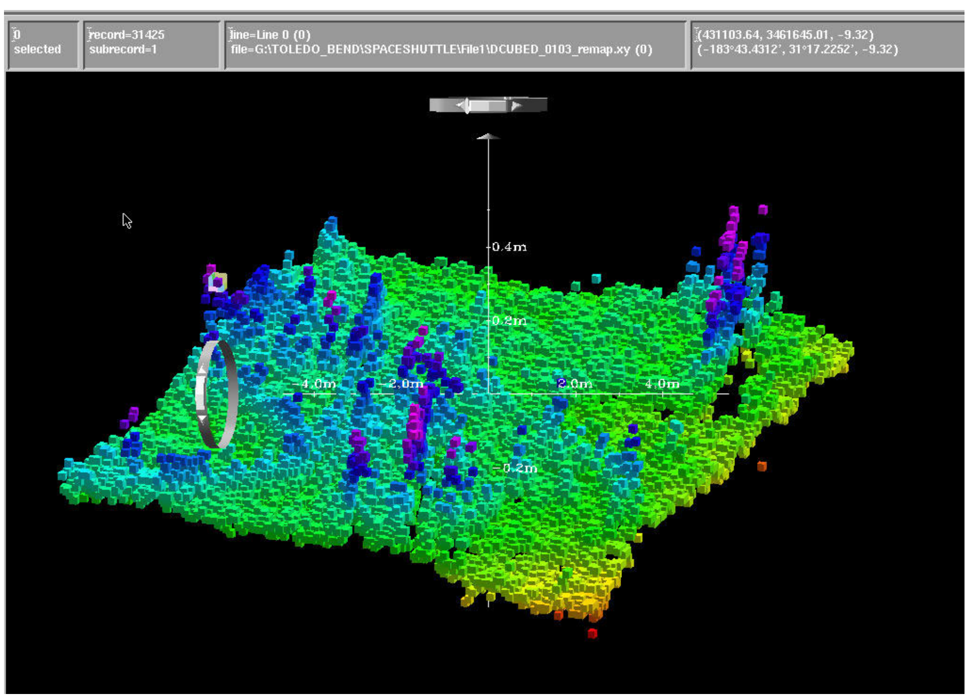


Figure 5. top: plan view of individual soundings in region on interest. Plan view allows evaluation of spatial distribution of targets. Bottom – 3-D perspective of individual soundings allows both spatial and vertical shape of target to be evaluated.

Despite this approach, it is clear that we cannot unambiguously identify targets other than standing or fallen trees. It is also still not clear that we can even resolve a target of the dimensions of the OEX, though, in theory, on an uncluttered bottom, we should be able to. The calibration trials will be important in establishing the limits of resolution and the backscatter response of small targets.

CALIBRATION TEST SITE:

On 11 March, Doug Lockhart organized a survey of a small area off the Fin and Feather that will be the focus of the calibration tests. Thirty-six lines were run over an approximately 250 m x 125 m area with depths between 7 and 10 m. We have extracted the raw soundings from this survey (>10 million) and display them here both unedited (Figure 6a) and processed through CUBE (Figure 6b).

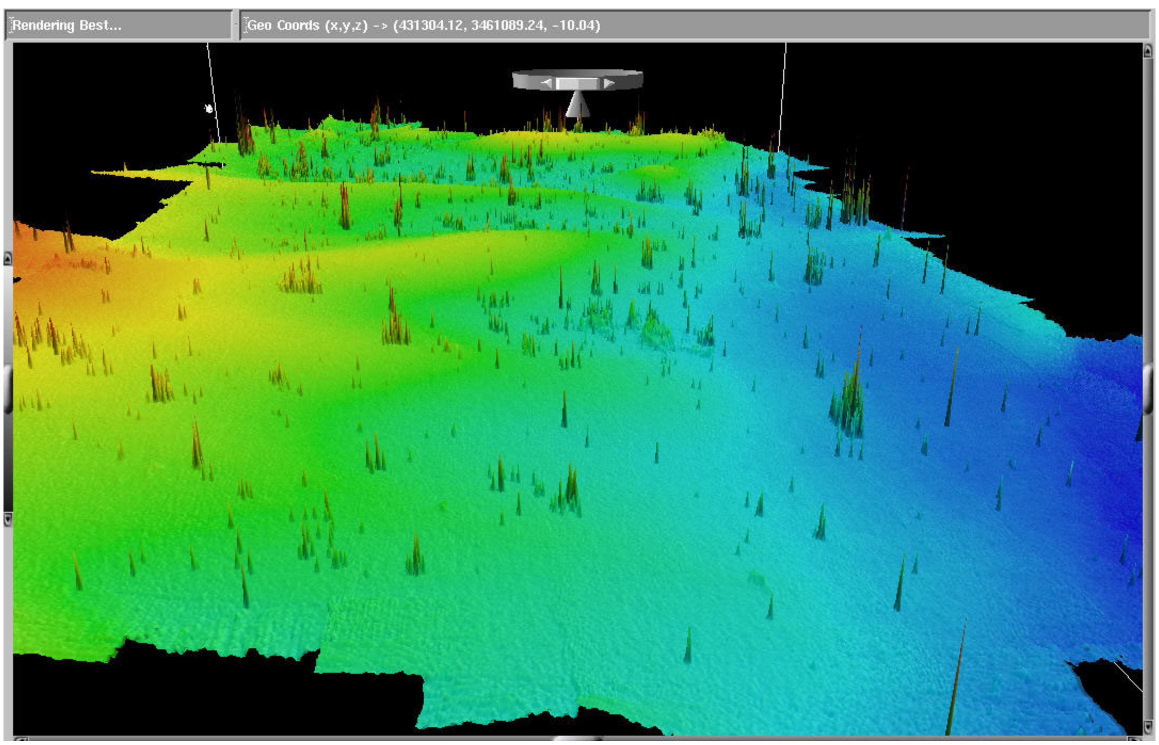


Figure 6a. 10 cm gridded surface for Test Area from raw unedited data. Note number of outliers that represent, fish, trees and other noise sources.

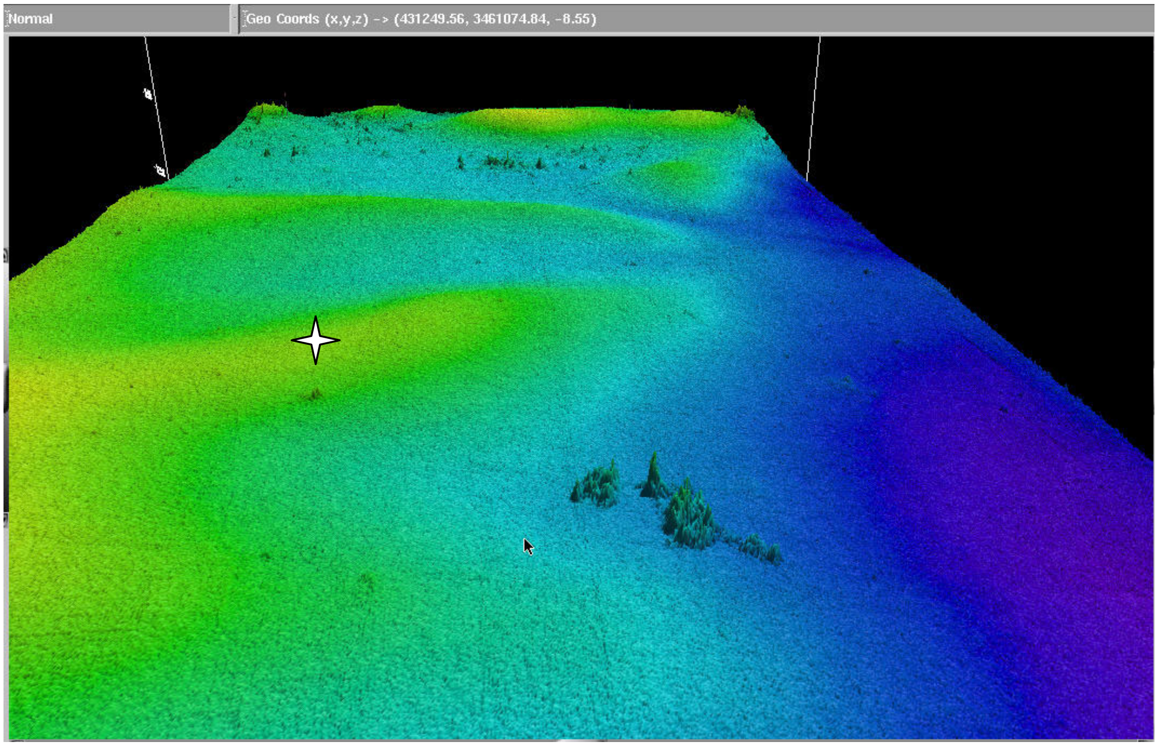


Figure 6b. Output of CUBE for Test area – 10 cm grid. Data has been automatically cleaned of outliers and other noise sources. Targets that are continuous with the bottom but not more than 2 m above the bottom have been eliminated (this can be changed by user). Small target under star is approximately 10 cm high.

Next – drape backscatter over bathymetry (Figure 7).

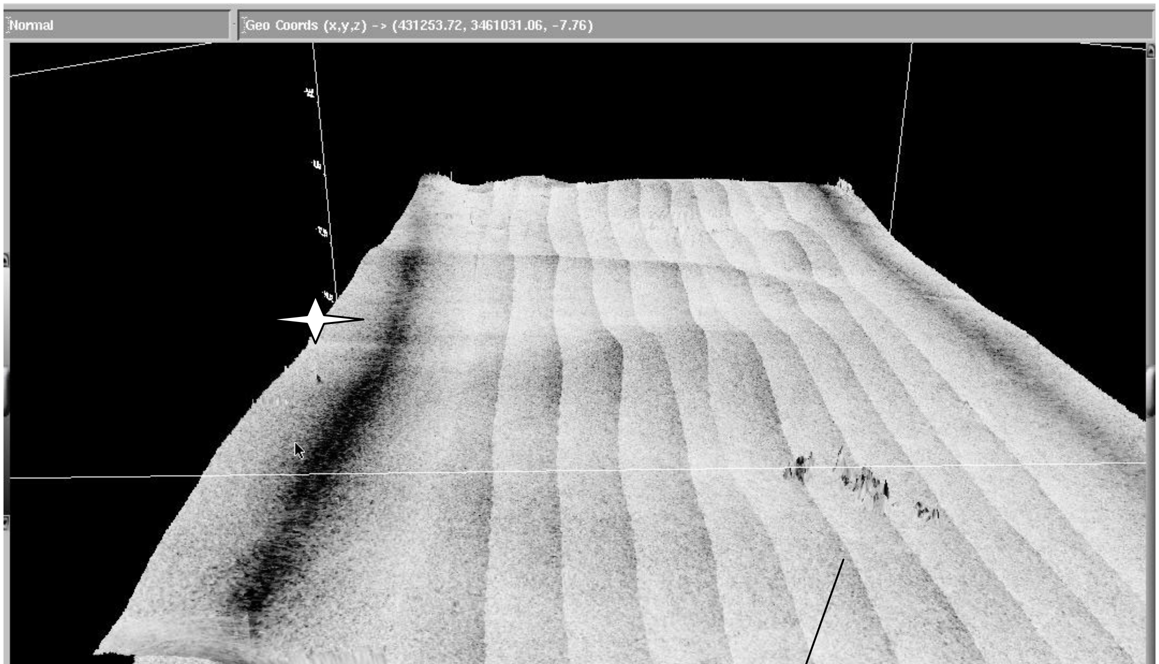


Figure 7. Backscatter draped over CUBED bathymetry – not correlation between backscatter and small targets

Evaluate objects by using point class (PFM) (Figure 8).

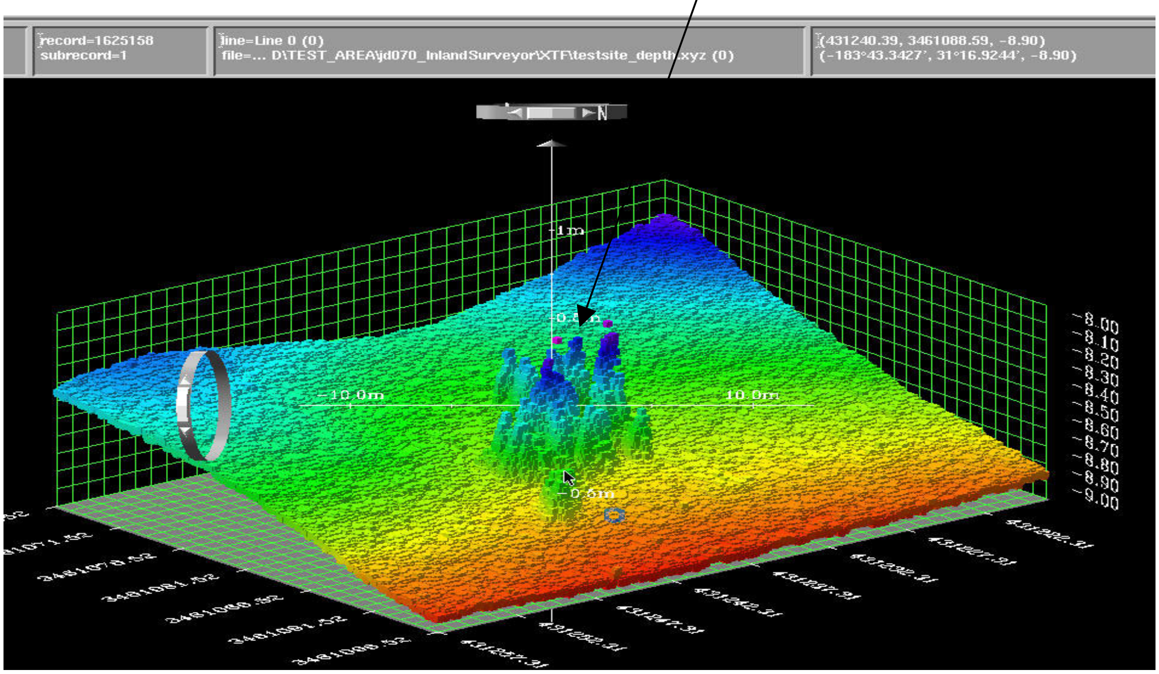


Figure 8. Individual points from target above viewed in 3-D

Sonar Range vs. Target Acquisition In The Klein 3000 Side Scan Sonar As Related To Columbia Search Operations

Prepared for: Supervisor of Salvage
U.S. Navy

Prepared by: Vincent J. Capone, M.Sc
And Rick Hogan
Phoenix International, Inc.

Introduction

Search operations for debris from the space shuttle Columbia include several large bodies of water. The Navy is currently employing several sonar systems to detect submerged debris. The following report is a preliminary summary regarding the probability of detecting small targets at various sonar range settings.

In general the performance of any given sonar is dependent upon the manufacturer's design (Frequency, signal to noise ratio, etc.) and operational parameters (Range, Boat Speed, etc.) While technical and electronic factors affect the sonar's ability to detect targets, these are a result of the sonar design and cannot be manipulated by field operations. The better the sonar design the higher the resolution at a given range and survey speed.

This report focuses on maximizing the field controllable parameters to insure detection of high value targets while maximizing the efficiency of the search operation.

Operational Sonar Resolution

Theoretically the sonar resolution is related to frequency. The higher the frequency the higher the theoretical resolution due to a smaller pulse length. In a very simplified model, the 500 kHz Klein System 3000 can detect objects a few inches in diameter. However under operational conditions other factors override the theoretical possibilities and determine the ability of the system to detect a target.

The operational resolution of sonar is directly affected by two components; 1) sonar range and 2) boat speed. The longer the range and faster the boat speed the lower the probability of detecting the target. These parameters are directly related to the physics of the sonar pinging through the water column. At a given range the sonar pings a set number of times. According to boat speed the survey will travel a given distance per ping.

The number of pings on a target is the primary building block for detecting and identifying a target. The greater the number of pings on target, the higher the probability of successfully identifying the object. Sonar range and boat speed effectively determine the number of pings across the bottom.

- Longer ranges have slower ping rates
- Faster boat speeds reduce number of pings per meter of bottom

Thus how do we determine the greatest speed and range to successfully locate the objective in the most time efficient manner? The key to making an accurate determination depends upon dimensions of the high value target. By knowing the size of the target we can determine the minimum requirements of speed and range to detect and identify the object.

Large objects such as a shipwreck can be detected at long range and higher speeds. Small targets such as mines or other high value targets are more difficult to detect. The first criteria, is to completely cover the lake bottom. An exaggerated example is as follows. If the ping rate was once a second and the survey vessel was moving at 10 meters per second the sonar would only have data for every ten (10) meters. There would be gaps in the record and a one (1) meter object between pings would be missed. So the first criteria, is to cover 100% of the bottom. The second criteria, is to get enough pings on the target to discriminate or identify the object.

Target Detection

There are two components to target detection. 1) Actual target detection. 2) Target discrimination.

The ability for a given sonar system to detect a target is different than being able to identify a target. It would be relatively easy to detect a small metal target on an uncluttered sandy bottom. When the bottom is complex, i.e. covered with trees, cluttered with weed or peppered with fish, the sonar must provide enough information not only to detect the target but also allow the operator to identify the target from amongst natural background.

The current search environment in Toledo Bend Reservoir has numerous targets, stumps, fish, etc. thus more pings on a target increase the probability of identification.

Based upon experience and back calculations of existing data, an experienced operator would need five (5) to eight (8) pings on a small target to *identify* the object. Ping rates for the Klein 3000 are shown in Figure 1.

Fig. 1 Klein Sonar Range vs. Ping Rate

Sonar Range Setting	Ping Rate
50 meters	15 Pings per second
37.5 meters	22 Pings per second
25 meters	30 Pings per second

Other Operational Considerations

Other operational parameters can degrade the sonar records even when speed and range are optimal. Parameters such towfish height, towfish motion (such as caused by sea state or heading changes), and bottom conditions can reduce the probability of detecting and/or discriminating targets.

Towfish height when optimal increases the presence and size of target shadows. Shadows increase the probability of detection and allow for better target discrimination. The higher the towfish the smaller the shadow.

Due to standing trees in the reservoir, the towfish must be kept higher than normal, during search operations. While not optimal the towfish height cannot be changed and the impact on the search operation incorporated into the overall search strategy.

Towfish motion causes the sonar to cover ground inconsistently. High sea states or poor boat driving can cause coverage gaps and areas of poor data. Conditions on the lake and skill of boat drivers seem to have limited the effects of such problems.

Cluttered bottoms such as those with trees, stumps, fish, bushes, etc., reduce the probability of identifying the targets amongst the natural objects. In the Toledo Bend environment many stumps have approximately the same proportions as some of the high value targets. Thus extra caution must be exercised when analyzing targets.

Many standing trees obscure portions of the record reducing the probability of detecting the target by obscuring objects.

Summary

Based upon all the aforementioned factors search operations utilizing the Klein system 3000 should be limited to 37 meter range with a maximum survey speed of 2.5 knots. Under ideal conditions small high value targets would be detected on a reasonably consistent basis.

Under current conditions, the search environment reduces the probability of consistently detecting and identifying small high value targets. There are a large number of submerged stumps, standing trees and other bottom obstructions. Normally reducing the sonar range to 25 meters would increase the probability of detection and identification. However due to the large search area and high towfish altitudes reducing the sonar range to 25 meters is not a viable option.

In summary the probability of detecting and identifying small high value targets in the current environment is low except in areas free of vegetation. As soon as the Klein 3000 is available at Toledo Bend we recommend a series of passes over the test targets at different range scales.

Thales GeoSolutions

Toledo Bend

Testing Program

THALES

Space Shuttle Columbia Search

And Recovery

Toledo Bend Testing Program

TGP-2628-TMA-01-00

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REPORT CERTIFICATION

FOR

P2628
Space Shuttle Columbia Search And Recovery

Toledo Bend Testing Program

TGP-2628-TMA-01-00

This issue of the report has been approved by:

1. Area Surveyor Doug Lockhart

This report has been distributed to:

1. Phoenix International 1 copy

The following versions of this report have been issued:

00	06/03/2003	Draft Issued for Comment	DLL	DLL
1				
2				
REV	DATE	DESCRIPTION	ORIG	APPR
DOCUMENT CONTRIOL AUTHORITY				THALES

Contents

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Tables

1. Executive Summary

A test program was designed to address fundamental issues of target detestability and discrimination. The goal of the testing program can be generally defined by three specific questions.

1. Can survey systems find targets the size of the OEX recorder?
2. Can survey systems be tuned differently for optimal performance?
3. Are there any other systems that can offer improved target delectability?

Item 1 was addressed in considerable detail. Item 2 received cursory attention however; it does appear that there is little that can be done to improve data quality through alternative tuning. Some effort was spent on item three with little effect.

Test Ranges

- Test Range 1 (TR1) was established in 8-10 m water depths just North of the Fin and Feather Resort and Recreation Area. Nine targets were deployed in a line. A sonar reflector constructed from side scan tow fish tail fins was used for the first and last target. All systems listed below were used to survey the test range. Survey lines ran along the length of the target line at 5-meter offsets to the north of the target line. Four tie lines ran between targets 3 –7. After an initial review of the data, it was determined that sonar returns from the buoys and clump weights on each target were interfering with the system assessment. Buoys and clump weights were removed from all targets except the end reflectors and the range was re-surveyed by representative systems.
- Test Range 2 (TR2) was established in 17-20m water depths near the site of the submerged pickup truck. 7 targets were deployed. The first and last targets were reflectors made from Norwegian buoys anchored about a meter off the bottom by 3 clump weights. Survey lines were set up on a 5-meter interval on both sides of the target line; tie lines between every target.
-

System Results

Reson 8125

- System sees targets in backscatter on TR1.
- System sees targets in bathymetry on TR1.
- OEX mock-ups can be seen in backscatter on TR3. Targets appear to ring.
- PC targets cannot be seen in the backscatter TR2.
- Targets cannot be seen in bathymetry in TR2.
- Target positions in TR1 are generally within 2 meters of as laid positions
- Target positions in TR2 are generally within 5 meters of as laid positions. Most of the error may be in the target position and not in the MBES navigation.
- Bathy data can be used to eliminate many false targets

- The 8125 pings at roughly one half of the expected rate for any given range. This feature is noted in the 8125 manual. Ping rates are:

Range	Expected Ping Rate	Actual Ping Rate
25	30	14
40	18.7	8.6
50	15	7

Reson 8101

- System sees targets in backscatter on TR1.
- Targets not seen in Bathy on TR1.
- Targets not identifiable in backscatter on TR2.
- Bathy data cannot be used to eliminate false targets.
- Ping rates match expected rate for a given range.

Klein 3000

- System sees targets on TR1.
- System sees targets on TR2. OEX targets appear somewhat unique. PC targets do not appear to be unique.
- Ping rates match expected rate for a given range.
- Klein SonarPro can miscalculate target positions. Error is equal to the difference between the slant range and the ground range from the towfish to the target.

Marine Sonic

10° down-look 600 kHz Custom Tow Body

- System sees targets on TR1.
- Targets are generally identifiable as man made.
- Targets not seen on TR2.
- Positioning is generally within 2 meters but can be in error if the range delay obscures the seafloor return.

10° down-look 900 kHz Custom Tow Body

- System sees targets on TR1.
- Targets are generally identifiable as man made.
- Targets not seen on TR2.
- Positioning is generally within 2 meters but can be in error if the range delay obscures the seafloor return.

5° down-look 600 kHz Soft Tow

- System sees targets on TR1. Targets are not as pronounces as 10 degree system.

5° down-look 600 kHz Pole Mount

- Marine Sonic pole mount data was collected during a period of rough weather.
- System see buoys but not targets. Weather related noise dominates record.

5° down-look 1200 kHz REMUS

- System sees targets on TR1
- A large navigation error (~80m) was noted during the first REMUS run.
- Subsequent REMUS trials resulted in 9 – 16 meter errors.
- Consultation with REMUS manufacturing revealed that REMUS positioning is specified to 25 m.

Edgetech MPX multipulse FM 400 kHz

- System sees targets on TR1.
- System sees targets on TR2. OEX targets appear somewhat unique. PC targets do not appear to be unique.
- There is no easily discernable difference between 2 and 3 ping operation.
- Waveform selection does have some effect on the appearance of the targets but does not appear critical in detecting targets on TR1.
- Tow fish is large and heavy. Large fins are at risk in wooded areas.

Single Beam 24/200 kHz

- System does not see targets on TR1 with any repeatability.
- No appreciable parabolic reflections.
- System sees trees, stumps and other clutter in wooded areas.
- System is difficult to deploy.
- Fathometer recorder is difficult to tune.

2. Introduction

The report details the sonar-testing program undertaken at the Toledo Bend Reservoir in support of the Space Shuttle Columbia Search and Recovery effort. The initial goal of the testing program was to determine which particular sonar could, most effectively, locate and identify objects that may have come from the Shuttle Columbia.

Tests were carried out on two different test ranges using a number of sonar targets. In most cases all sonars detected targets in Test Range 1 (TR1). Performance in Test Range 2 (TR2) was not as favorable. Both testing procedures and results are highlighted in the following sections.

The test program was designed to assist in the shuttle search and recovery operation.

All positions are in WGS84.

Estimations of backscatter strengths, signal to noise ratios and target strengths are made in Decibels throughout this document. For these estimates, the total dynamic range of the system is taken as the 8-bit bandwidth of the display or 48 dB. Any processing algorithm run on any particular data set would have access to the 12 or 16 bit raw data, depending on the system, and would have more dynamic range to work with. The estimates made here are for the convenience of comparing multiple systems and should not be taken to suggest a calibrated result or measurement of backscatter or target strength.

- Reson 8125 Multibeam Sonar, 455 kHz
- Reson 8101 Multibeam Sonar, 240 kHz
- Klein 3000 Side Scan Sonar, 100/500 kHz
- EdgeTech MPX FM Multipulse Side Scan, 400kHz
- Marine Sonic Side Scan Sonars
  - 10° Down look, 600 kHz
  - 10° Down look, 600 kHz
  - 5° Down look, 600 kHz
  - 5° Down look, 1200 kHz (REMUS)
- Single Beam Echo Sounder 24/240 kHz configured as a side looker

3. Positioning

Position solutions for all navigation and target deployment were provided by C-Nav, a global decimeter positioning solution offered by C&C Technologies. The position was fed into Thales WinFrog for line driving and display. Survey vessels were also fitted with TSS Meridian gyros for heading.

4. Test Ranges

Two test ranges were established at Toledo Bend. Test Range 1 (TR1) was constructed in clear terrain and relatively shallow water. TR1 was selected to give the sonars a nearly optimal chance to locate targets. Target signatures from TR1 could then be used to help identify targets in cluttered areas.

Test Range 2 (TR2) was constructed in a relatively deep and cluttered area. The site was selected to be similar to the vast majority of the lake bottom where target identification is difficult or impossible.

4.1. Test Range 1

4.1.1. Range Description

Test Range 1 (TR1) was installed within sight of the Fin and Feather Resort on a relatively clear and flat section of lakebed. The entire area was surveyed at 400% coverage with a Reson 8125 to make sure that the test line was clear of any debris. Data was logged using Reson 6042 software and latter converted into the XTF format. Vessel offsets are coded into the header of the XTF files.

The area slopes gently to the North and appears to have been cleared prior to flooding. Average depth of the range was 9.5 meters. Depths over the entide range did not vary by more than 1 meter. Relic caterpillar tracks are visible in the western end of the area as seen in Figure 3. A large debris pile was located in the center of the area toward the eastern end. This pile is visible in the bathymetry, Figure 1, and backscatter, Figure 3. Divers found this to be a pile of corrugated sheet metal, possibly from a boathouse enclosure. Divers subsequently removed most of the pile although it was not directly in the selected target line.

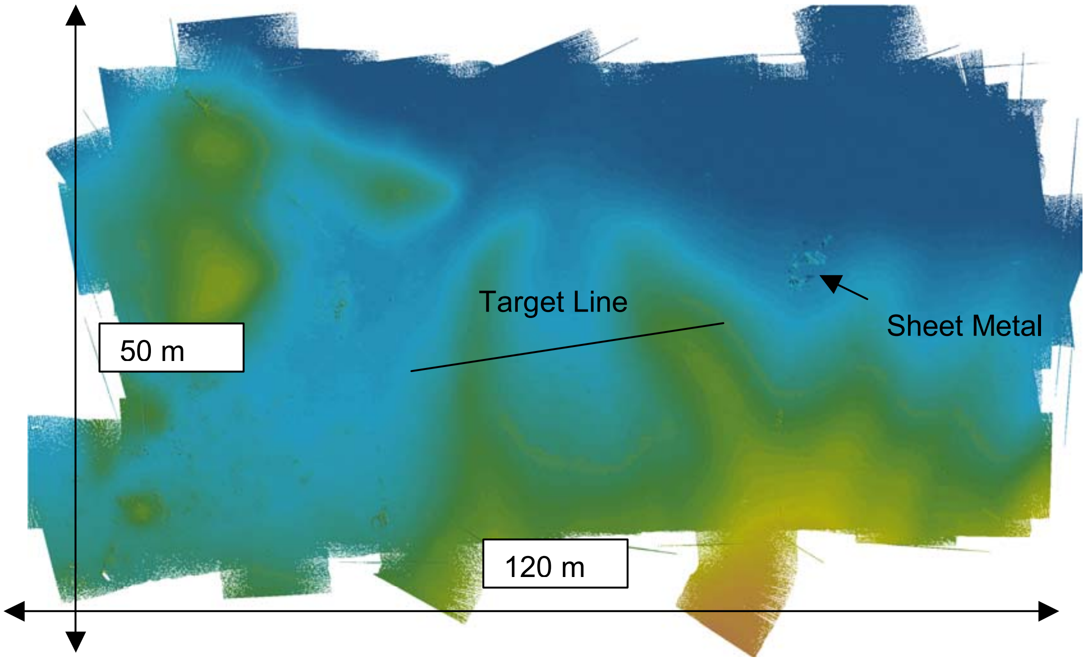


Figure 1: Test Range 1 (TR1) bathymetry showing approximate target line

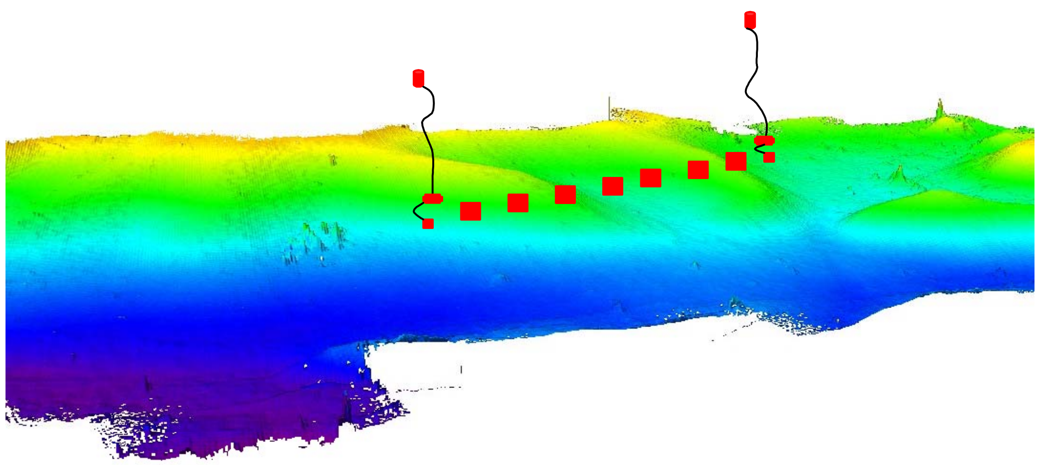


Figure 2: TR1 View from North with approximate target line

Variance in the backscatter from the 8125 is roughly 14db in the mosiac shown in Figure 3. Some of the highs and lows may have been clipped in the processing so raw data variability could be somewhat higher. The sheet metal pile is about 22 db over the surrounding data.

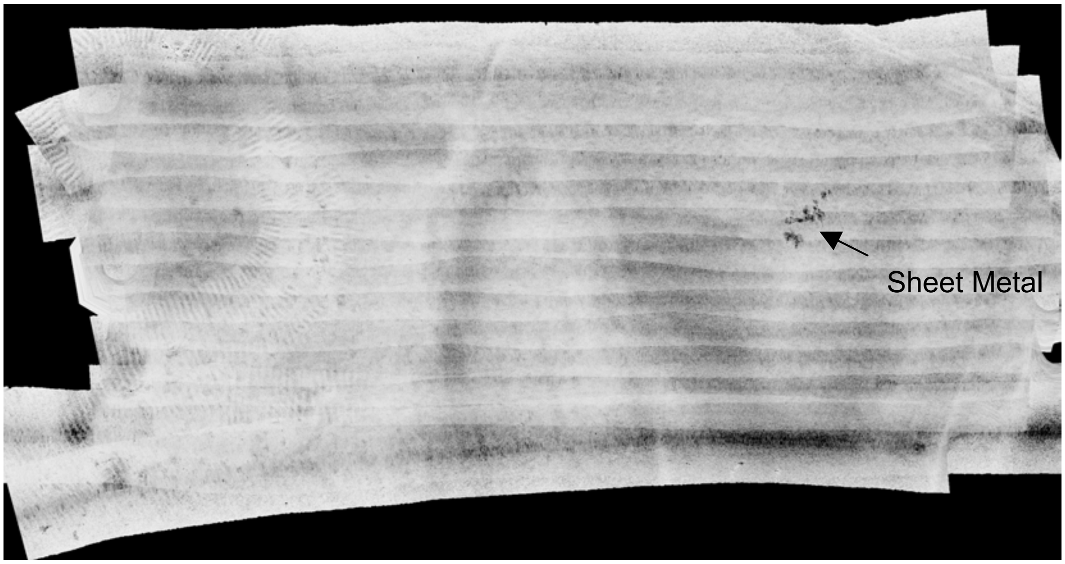


Figure 3: TR1 backscatter mosaic. Source: Reson 8125, 455kHz

Targets were laid at 10-meter intervals along a straight line. There were 7 targets in TR1, T1 through T7, and 2 end reflectors, R1 and R2. Targets were labeled west to east. The end reflectors were intended to be highly reflective sonar targets that would draw the interpreter eye to the target line. The reflectors used in TR1 were constructed of a pair of side scan towfish tail fine, suspended in the water column. A clump weight anchored the reflectors and a buoy kept then suspended in the water column.

Table 2, were anchored by a clump weight and marked with a buoy. After and initial set of tests, it was determined that the clump weights, chain, buoy line and buoy were strong enough sonar targets to make objective analysis of the systems impossible. Divers returned to the site and removed the clumps weights, buoys and tackle on all targets except the two end reflectors.

Care was taken in deploying and positioning the targets. A survey vessel using C&C Nav for positioning, a Gyro, and WinFrog for integrated navigation was used to place the targets. An offset point on the bow of the vessel was tracked. Targets were dropped and positioned at this point. The bathymetry from the pre survey was used to calculate buoy line lengths so that slack was at a minimum. Buoy positions were verified after installations and any required adjustment to the recorded position was made.

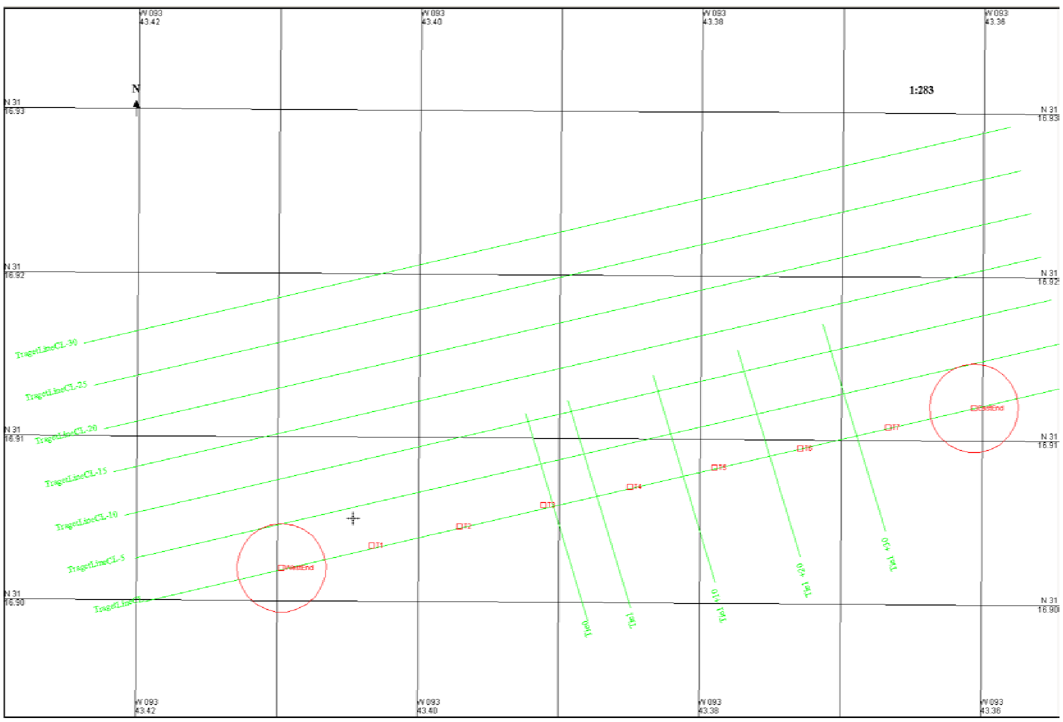


Figure 4: TR1 Survey lines with as-laid target locations.

4.1.2. Target Descriptions

Target locations for TR1 are given Table 1. Given the accuracy of the C&C Navigation system and the care used to place the target, positions are likely good to within 2-3 meters.

Table 1: Target as laid positions for Test Range 1

	WGS 84 DM.M		WGS84 D.D	
Target	**Lat (N)**	**Lon (W)**	**Lat (N)**	**Lon (W)**
R1	31 16.9020	93 43.4097	31.281700	93.723495
T1	31 16.9034	93 43.4033	31.281723	93.723388
T2	31 16.9046	93 43.3971	31.281743	93.723285
T3	31 16.9095	93 43.3911	31.281825	93.723185
T4	31 16.9071	93 43.3850	31.281785	93.723083
T5	31 16.9083	93 43.3790	31.281805	93.722983
T6	31 16.9095	93 43.3729	31.281825	93.722882
T7	31 16.9018	93 43.3667	31.281697	93.722778
R2	31 12.9120	93 43.3606	31.215200	93.722677

Table 2: Test Range 1 (TR1) Targets

	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

4.2. Test Range 2

4.2.1. Range Description

Test Range 2 (TR2) was established south east of the Fin and Feather resort in an area that can be loosely characterized as cluttered. Part of the area was covered by a submerged, standing forest, typical of much of the lake bottom. In the eastern third of TR2, it appears that the forest had been leveled, but not cleared, prior to flooding. A pickup was abandoned here, as seen in Figure 5 and Figure 6.

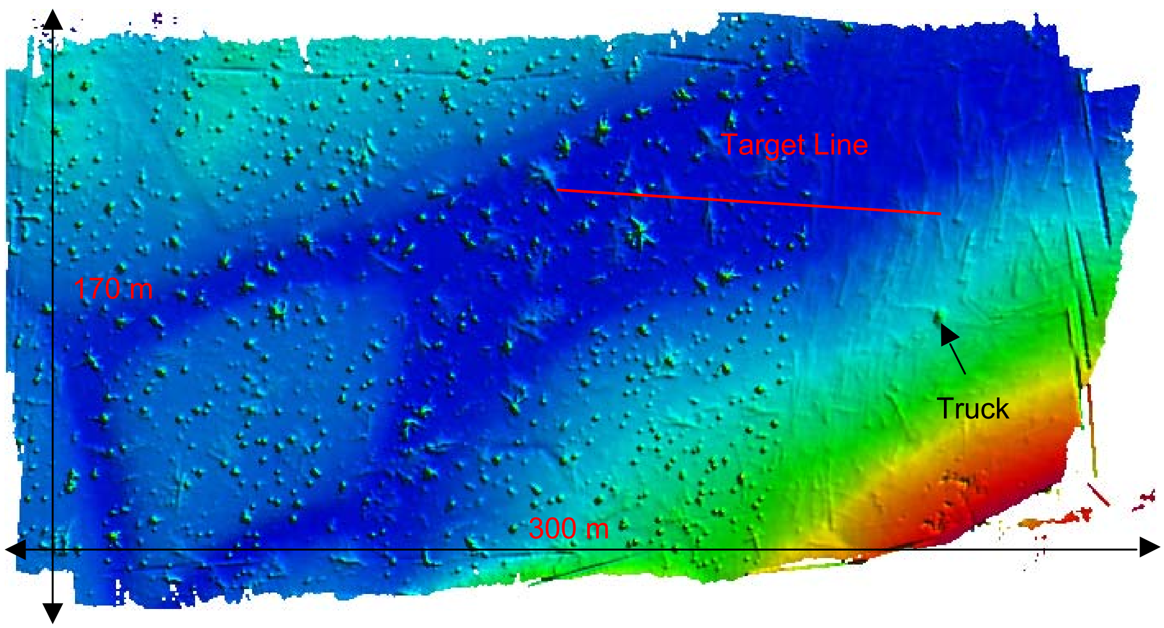


Figure 5: Test Range 2 (TR2) bathymetry showing approximate target line

Backscatter from TR2 is not well represented by a mosaic. The large number of vertical features in the water column simply adds noise and chaos to the mosaic. The mosaic is shown here to give a representative estimation of backscatter strengths from the area. Backscatter variance in this mosaic approaches the 48 dB level. Variance in the area of the truck is about 46 db.

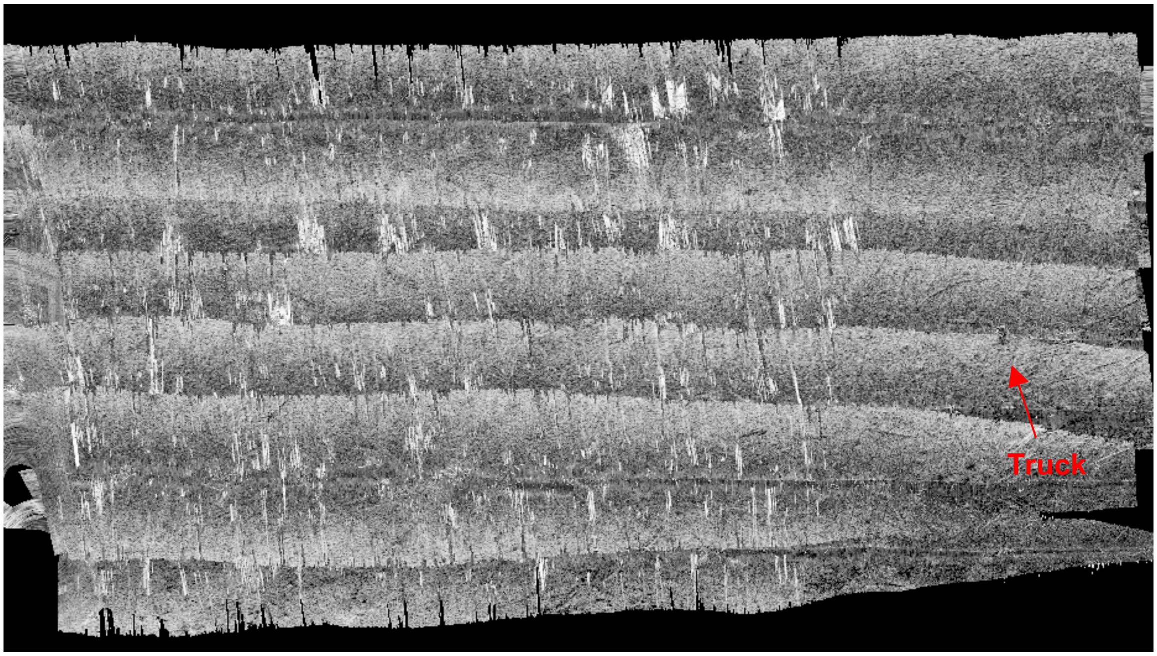


Figure 6: TR2 backscatter mosaic. Source: Reson 8125, 455kHz.

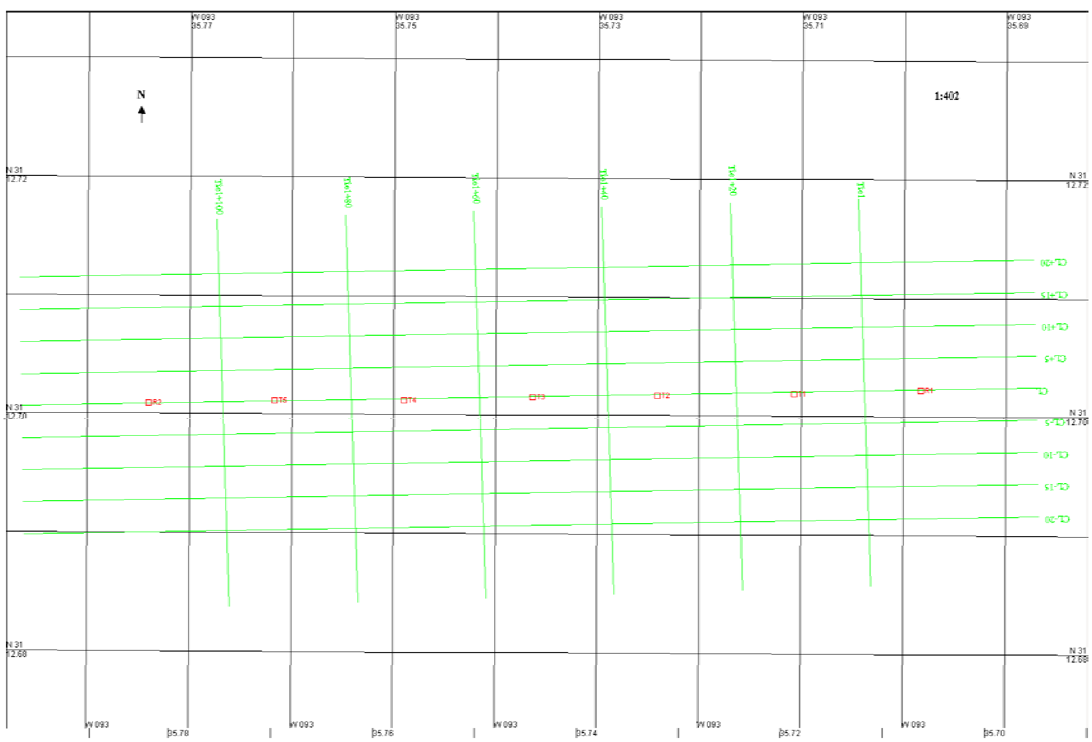


Figure 7: TR2 target positions and test line grid.

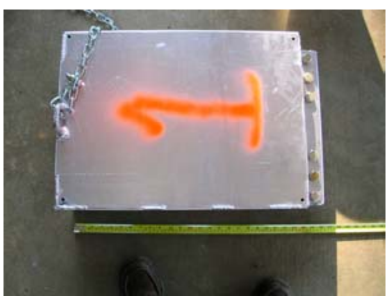
4.2.2. Target Descriptions

Target as laid positions are given in Table 3.

Table 3: Target as laid positions for Test Range 2

	WGS 84 DM.M		WGS84 D.D	
Target	**Lat (N)**	**Lon (W)**	**Lat (N)**	**Lon (W)**
R1	31 12.7028	93 35.6971	31.211713	93.594952
T1	31 12.7030	93 35.7116	31.211717	93.595193
T2	31 12.7027	93 35.7233	31.211712	93.595388
T3	31 12.7023	93 35.7362	31.211705	93.595603
T4	31 12.7012	93 35.7483	31.211687	93.595805
T5	31 12.7013	93 35.7608	31.211688	93.596013
R2	31 12.7022	93 35.7742	31.211703	93.596237

Table 4: Test Range 2 (TR2) Targets

Test Range 2 Targets	
	T3: OEX Mock up with 1 clump weight 
R1 : End Reflector Buoy with 4 clump weights. 	T4: PC with 1 clump weight 
T1: OEX mock up with 1 clump weight 	T3: OEX Mock up with 1 clump weight 
T2: PC with 1 clump weight 	R1 : End Reflector Buoy with 4 clump weights. 

5. Test Procedure

Every sonar used in search operations was evaluated in TR1. Sonars used in the Toledo Bend operation could not be deployed optimally due to the large numbers of logs, trees, stumps, and brush in the lake. The testing procedure used reflected the operational limitations placed on the systems. Selected systems were deployed in TR2 based on the results from TR1.

Both areas were surveyed prior to target deployment to determine the suitability of the test site and select an appropriate test line. The pre-survey also ensured that a baseline data set would be available if required.

5.1. Test Range 1

For all systems except the multibeam and REMIS, tow depth was set at 2 to 3 meters subsurface. For the sidescan systems, a towing altitude of 1 to 2 meters would have been preferable. But, since it was impossible to operate side scan systems in the lake using small towing altitudes, systems were not tested this way.

Each system was towed past the target line using the survey line pattern shown in Figure 4. For these tests, it was assumed that the sonars were adequately balanced from channel to channel and that there was no measurable difference in performance between port and starboard channels. So, for TR1, all test line were run on the North side of the target line in alternating directions. Tie lines were also run in case there was a strong directional bias in any of the targets.

An attempt was made to identify each individual target from each sonar. Some of the targets are not visible on some passes.

5.2. Test Range 2

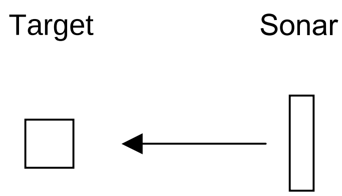
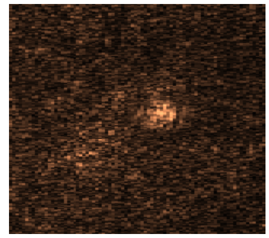
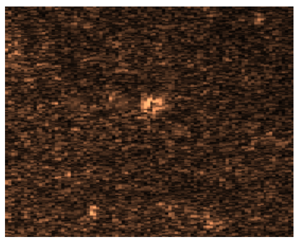
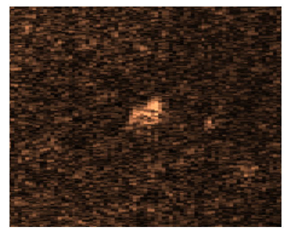
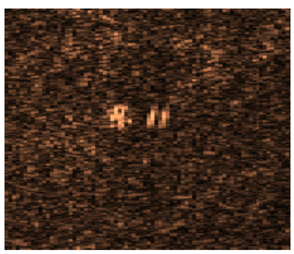
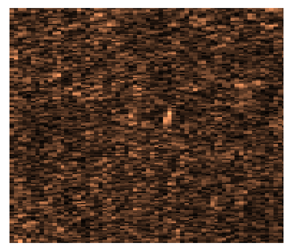
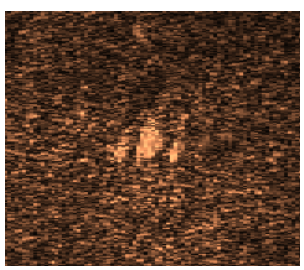
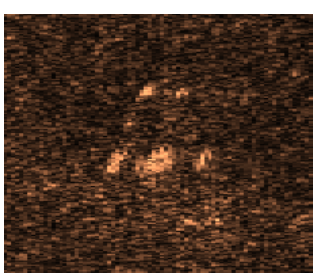
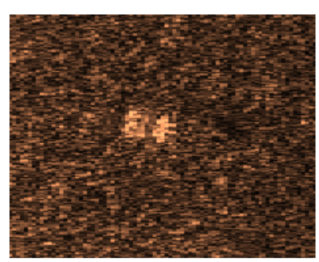
6. Sonar Test Results

Results of the tests for all sonars in both ranges are shown in the tables below. Target images are made from screen grabs of the waterfall display or from the playback software targeting utility. The diagram in the upper left panel of each table shows the relative positions of the sonar and the target.

As laid target positions were heavily relied on during target selection. For most systems, TR1 targets were easily spotted. Positions were required to absolutely identify the target. TR2 targets were nearly impossible to detect without the aid of the target position. The OEX mock up targets in TR2 (T1, T3, & T5) did produce a identifiable ringing signature on some systems. This signature was unique enough that it may have been selected without the aid of the position information.

6.1. Reson 8101

Table 5: Reson 8101 TR1 targets

Test Range 1 Targets	
Reson 8101  	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal
T3 OEX mockup, mesh on inside 	R2: End Reflector 

Reson 8125

Table 6: Reson 8125 TR1 targets

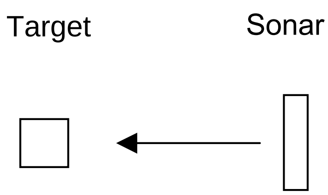
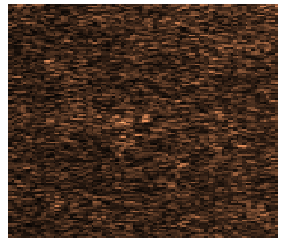
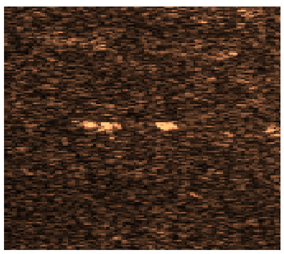
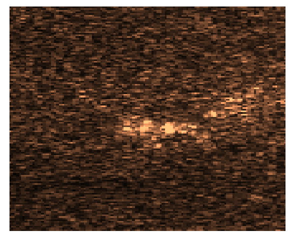
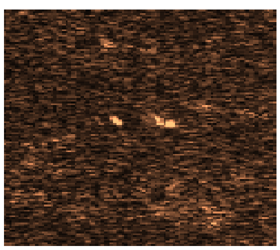
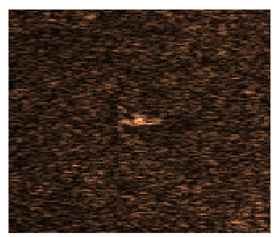
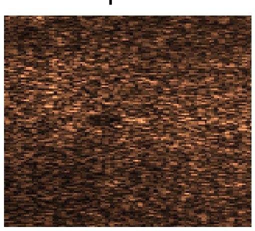
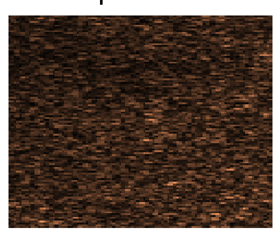
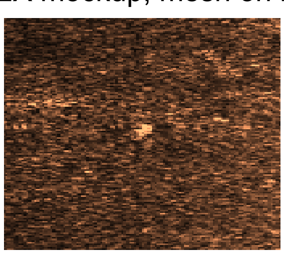
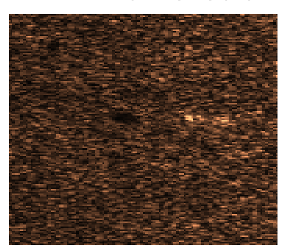
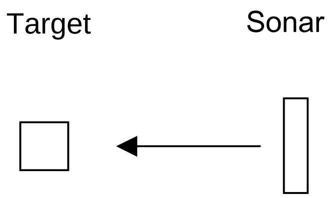
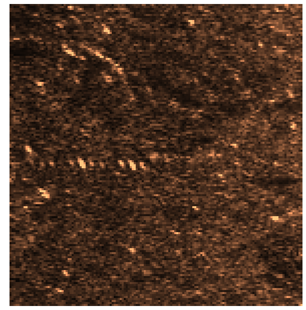
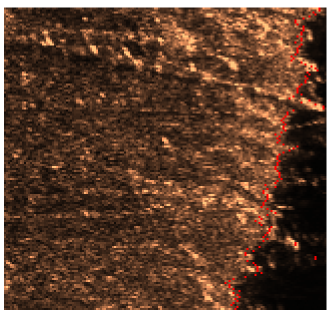
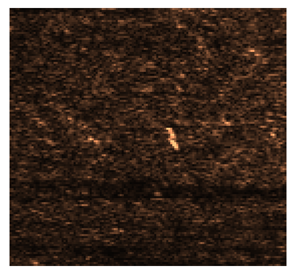
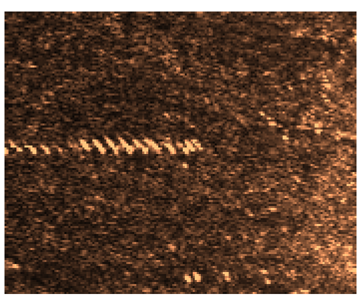
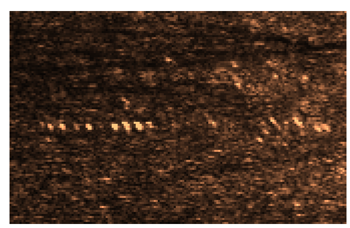
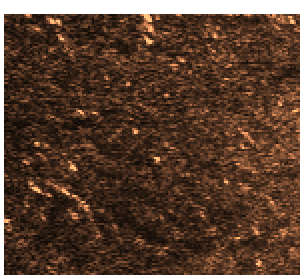
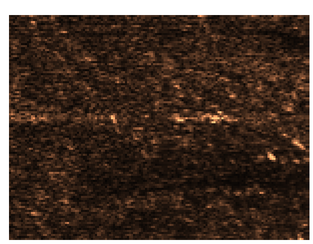
Test Range 1 Targets	
Reson 8125 	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

Table 7: Reson 8125 TR2 targets

Test Range 2 Targets	
Reson 8125 	T3: OEX Mock up with 1 clump weight 
R1: End Reflector Buoy with 4 clump weights. 	T4: PC with 1 clump weight 
T1: OEX mock up with 1 clump weight 	T5: OEX Mock up with 1 clump weight 
T2: PC with 1 clump weight 	R1 : End Reflector Buoy with 4 clump weights. 

6.2. Klein 3000

Table 8: Klein 3000 TR1 targets

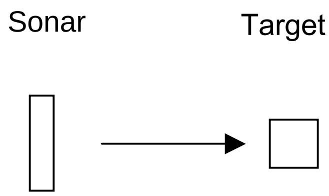
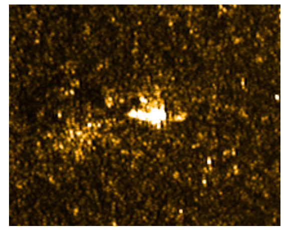
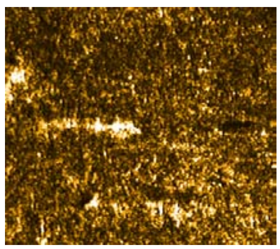
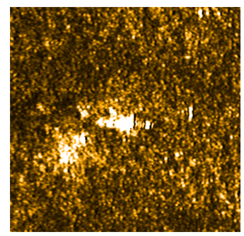
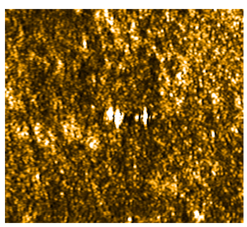
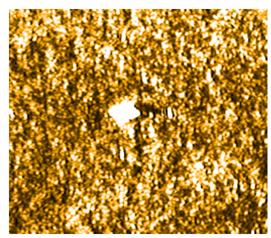
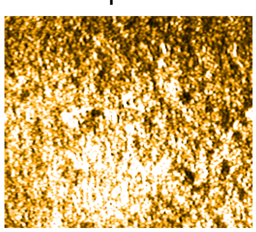
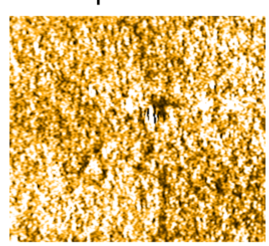
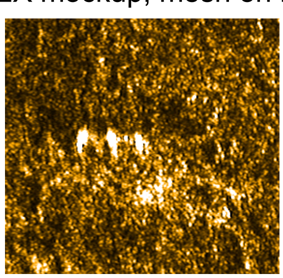
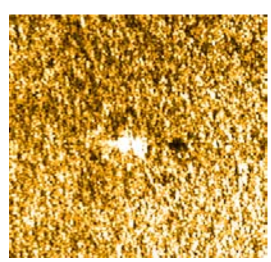
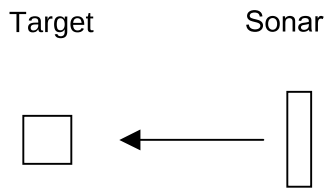
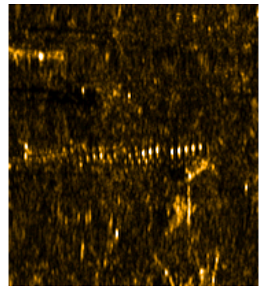
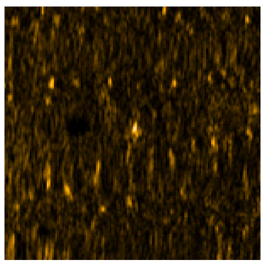
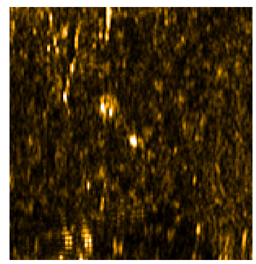
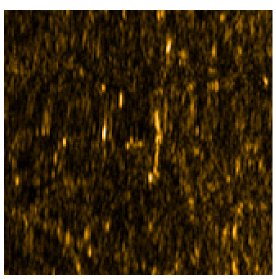
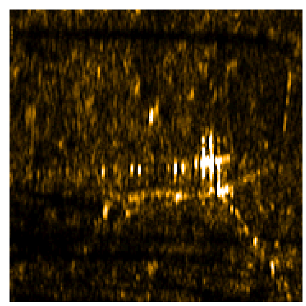
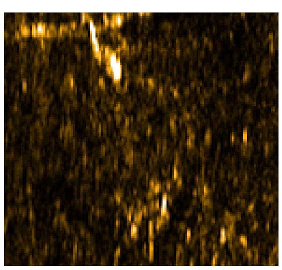
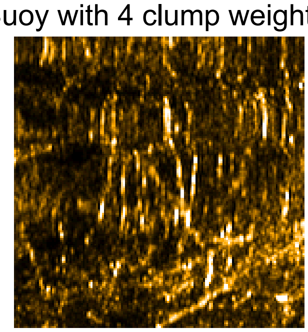
Test Range 1 Targets	
Klein 3000 	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

Table 9: Klein 3000 TR2 targets

Test Range 2 Targets	
Klein 3000 	T3: OEX Mock up with 1 clump weight 
R1 : End Reflector Buoy with 4 clump weights. 	T4: PC with 1 clump weight 
T1: OEX mock up with 1 clump weight 	T5: OEX Mock up with 1 clump weight 
T2: PC with 1 clump weight 	R1 : End Reflector Buoy with 4 clump weights. 

6.3. Edgetech MPX

Table 10: Edgetech MPX TR1 targets

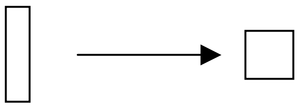
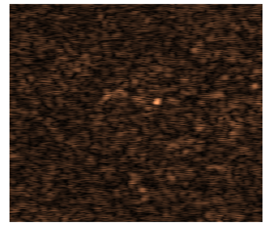
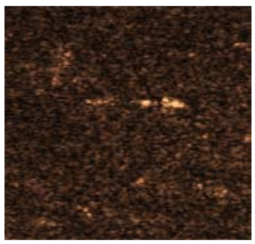
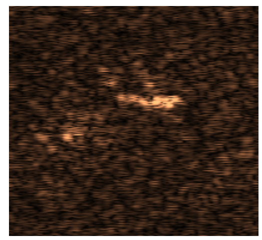
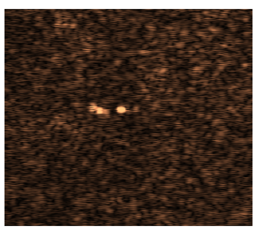
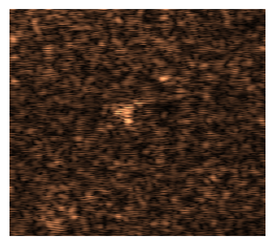
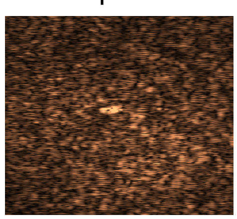
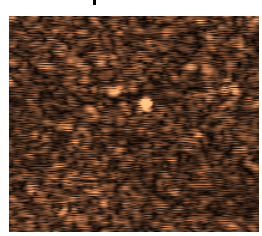
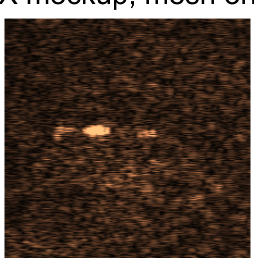
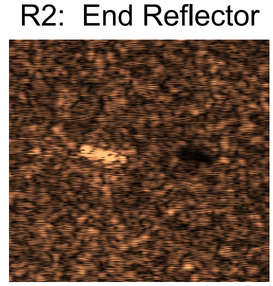
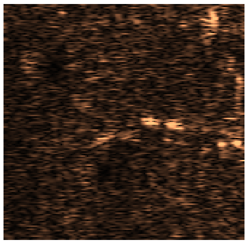
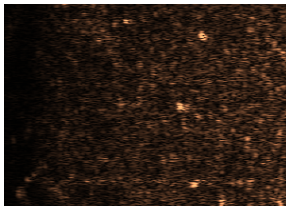
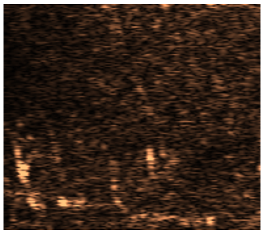
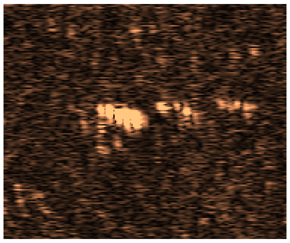
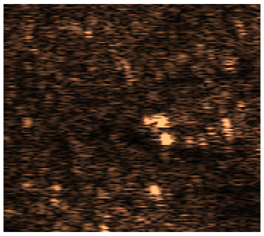
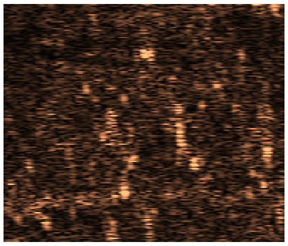
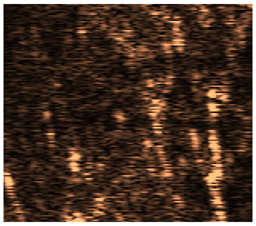
Test Range 1 Targets	
Edgetech MPX Sonar Target 	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

Table 11: Edgetech MPX TR2 targets

Test Range 2 Targets	
Edgetech MPX	T3: OEX Mock up with 1 clump weight 
R1 : End Reflector Buoy with 4 clump weights. 	T4: PC with 1 clump weight 
T1: OEX mock up with 1 clump weight 	T5: OEX Mock up with 1 clump weight 
T2: PC with 1 clump weight 	R1 : End Reflector Buoy with 4 clump weights. 

6.4. Marine Sonic Technology

6.4.1. Stock System

The target line in TR1 for the Marine Sonic is not readily identifiable. Positioning for this system also appears to be somewhat erratic. As a result few of the targets in TR1 are identifiable in the Marine Sonic records. Targets are visible in the records, as seen in Figure 8, but it is not possible to assign a particular sonar signature to any of the targets that were deployed. Figure 8also shows numerous fish schools.

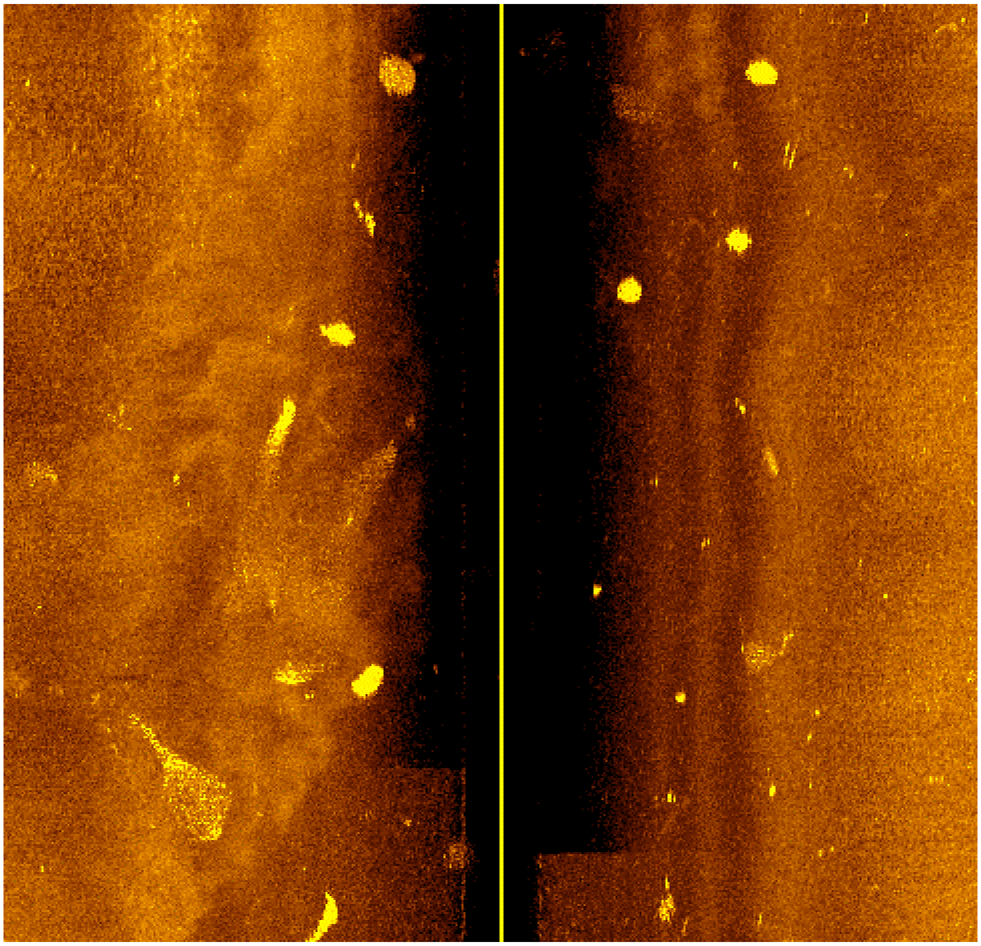
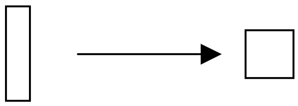
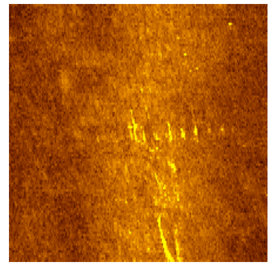
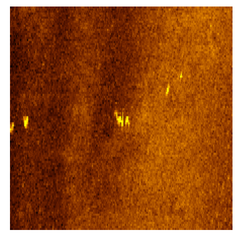
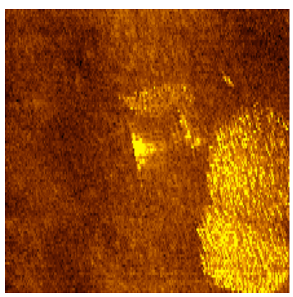
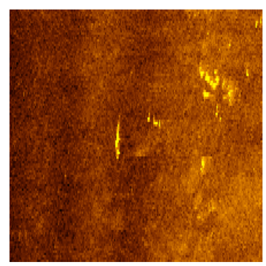
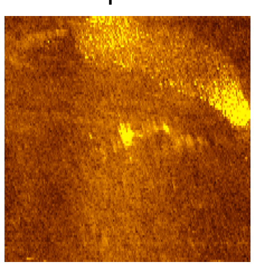
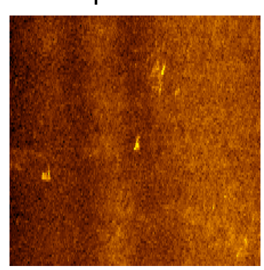
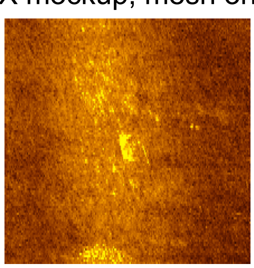
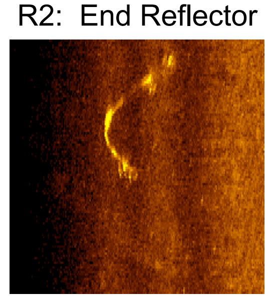


Figure 8: Marine Sonic stock system waterfall display

The samples shown in Table 12 consist of images taken from a pole mounted system (T1- T4) and a soft tow system (T5-T7 and R2)

Table 12: Marine Sonic 600 kHz stock system TR1 targets

Test Range 1 Targets	
Marine Sonic 600 kHz Stock System Sonar Target 	T4: Desktop PC case 
R1: End Reflector	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

6.4.2. Custom System

Table 13: Marine Sonic 600 kHz custom system TR1 targets

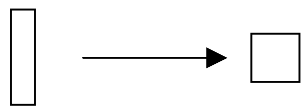
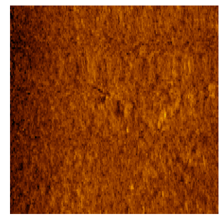
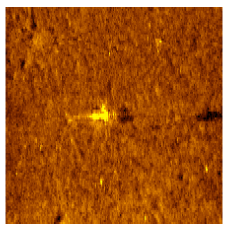
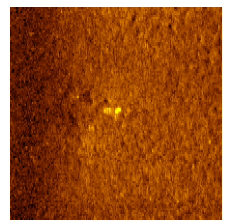
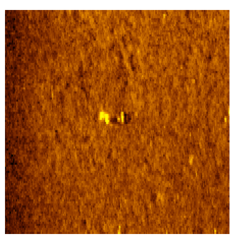
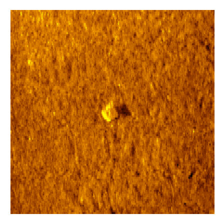
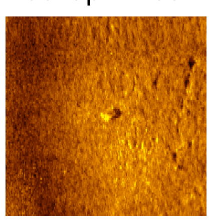
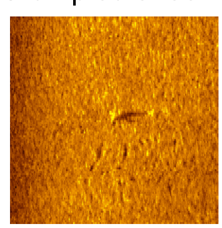
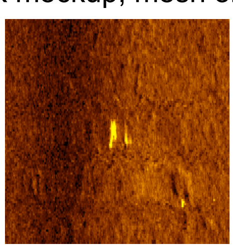
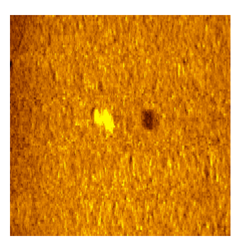
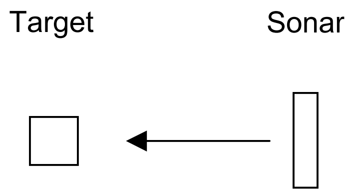
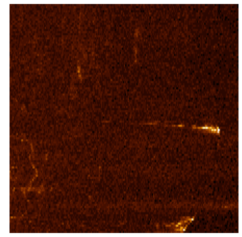
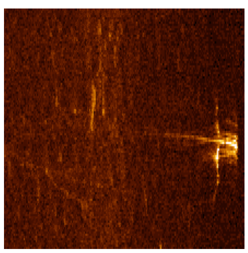
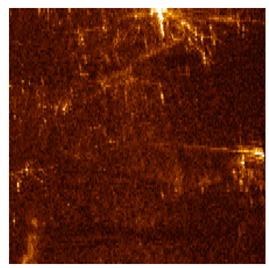
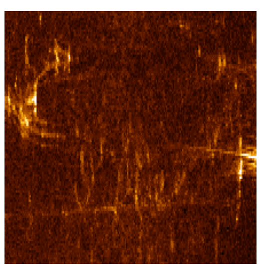
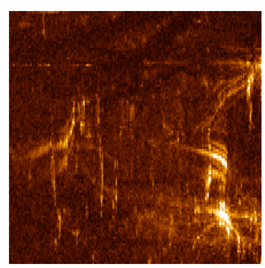
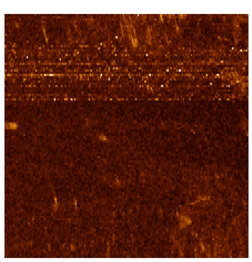
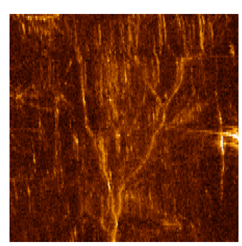
Test Range 1 Targets	
Marine Sonic 600 kHz Custom Sonar Target 	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

Table 14: Marine Sonic 600 kHz custom system TR2 targets

Test Range 2 Targets	
Marine Sonic 900 kHz Custom  	T3: OEX Mock up with 1 clump weight 
R1 : End Reflector Buoy with 4 clump weights. 	T4: PC with 1 clump weight 
T1: OEX mock up with 1 clump weight 	T5: OEX Mock up with 1 clump weight 
T2: PC with 1 clump weight 	R1 : End Reflector Buoy with 4 clump weights. 

6.4.3. REMUS

Table 15: REMUS-1 MS 1200 kHz TR1 targets

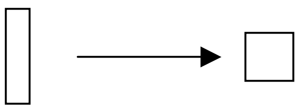
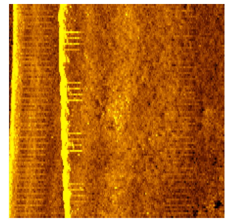
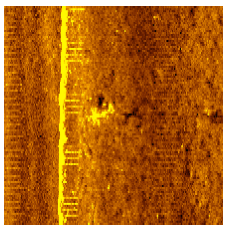
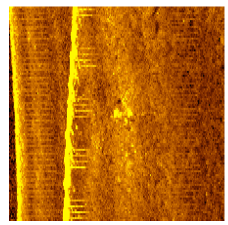
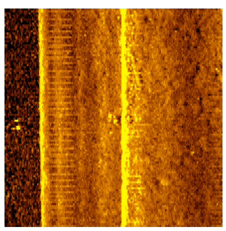
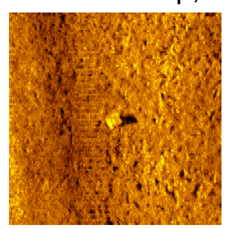
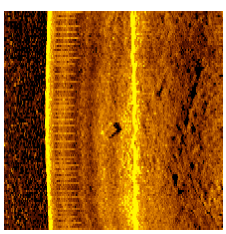
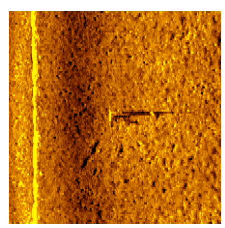
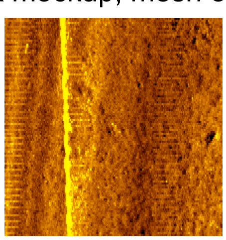
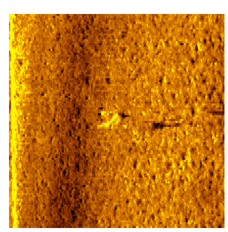
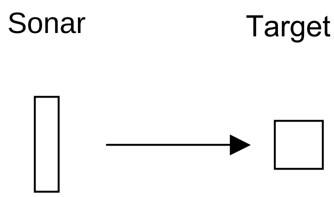
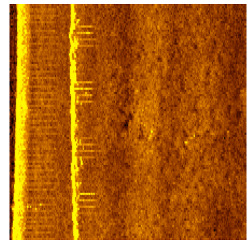
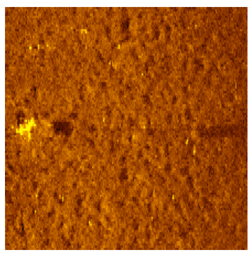
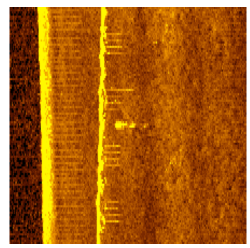
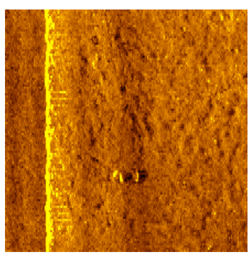
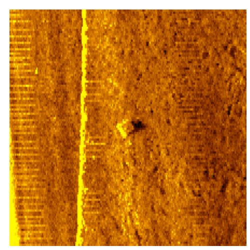
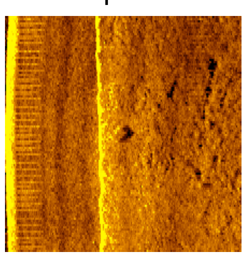
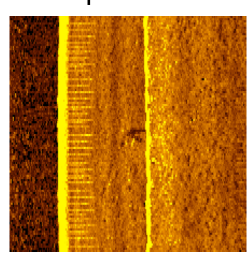
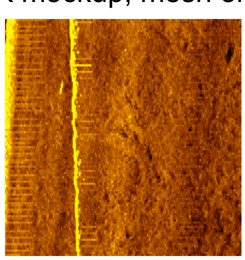
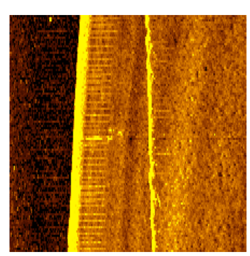
Test Range 1 Targets	
REMUS 1 Sonar Target 	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

Table 16: REMUS-2 MS 1200 kHz TR1 targets

Test Range 1 Targets	
REMUS 2 	T4: Desktop PC case 
R1: End Reflector 	T5: Tower PC case 
T1: Old tire 	T6: OEX mockup, steel 
T2: OEX mockup. Mesh on outside 	T7: Crumpled sheet metal 
T3 OEX mockup, mesh on inside 	R2: End Reflector 

6.4.4. Positioning

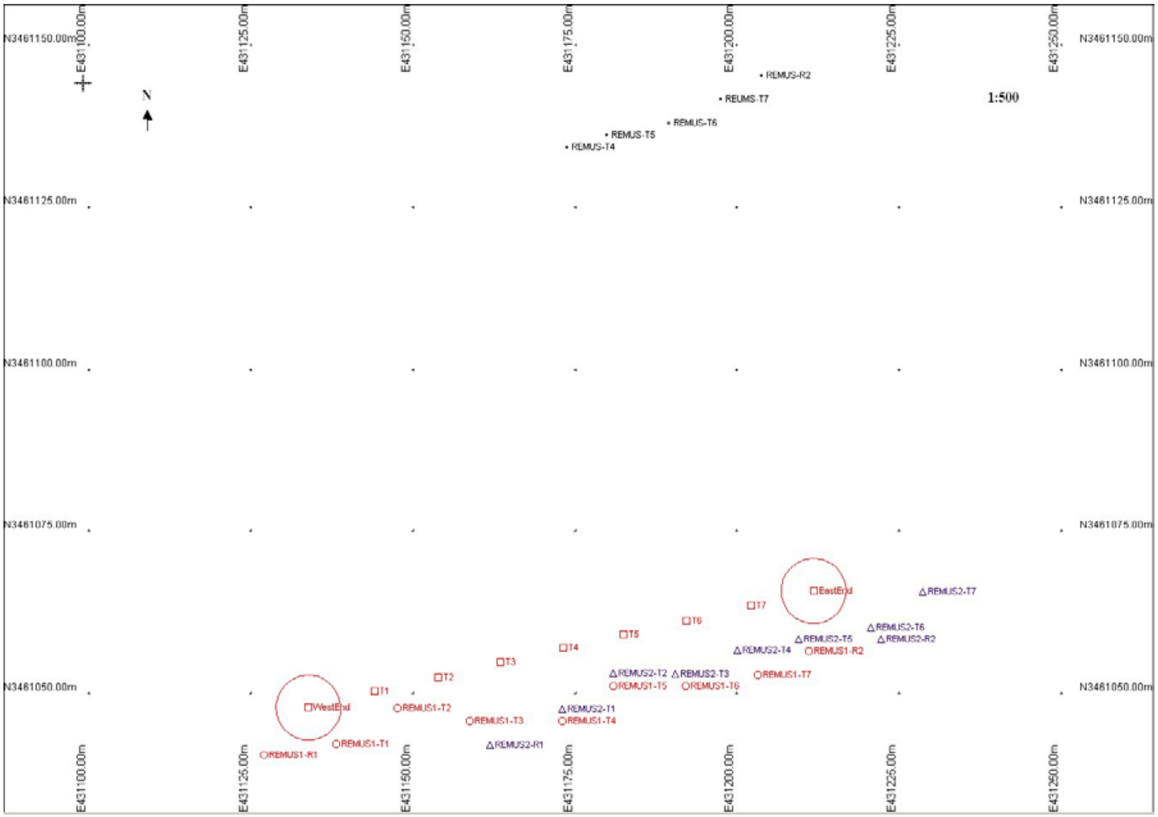


Figure 9: REMUS and as laid target positions

The Marine Sonic sonars on the REMUS AUV's were reported to be opwerating at 1200 kHz. This appears likely given the quality of the imagery from the REMUS vehicles. A good comparison to a 600 kHz Marine sonic system can be seen in Table 20. The REMUS log delivered with the REMUS data files, Figure 10, indicates that the sonar was operating at 300 kHz. This appears to be incorrect, judging from the imagery.

The REMUS vehicles did have difficulty position targets accurately. Table 17 shows the relative errors in target positions from three separate runs through TR1. The first run, resulting in an average error of about 78 meters, was though to be the result of bad transponder placement. Subsequent tests improved the positional accuracy to near or better then the 25 meter error specified by the system manufacturer.

Table 17: REMUS target positions

Target	REMUS Distance	REMUS 1 Distance	REMUS 2 Distance
R1		10.1	28.6
T1		10.0	29.1
T2		7.8	27.1
T3		10.2	27.2
T4	77.4	11.3	27.0
T5	77.1	8.1	27.0
T6	76.7	10.2	28.4
T7	78.1	10.8	26.6
R2	79.9	9.3	12.8
Average error	77.9	9.7	26.0

```
--------------------------------------------------------------
Start Message Record -----------------------------------------
       Date: Tuesday, March 18 2003
       Time: 13:02:53 (EST)
System Time: 8526



--------------------------------------------------------------
Start Message Record -----------------------------------------
       Date: Tuesday, March 18 2003
       Time: 13:02:53 (EST)
System Time: 8528

Message Text -------------------------------------------------
At the 100m range the pulse rate will be adjusted to maintain a fixed
data density of 3 pulses/meter.  As a result the image will be
distorted.  Features will be elongated transversely because they are
being oversampled (by 17%).
Prompt -------------------------------------------------------
Do you want to force a data density of 3 pulses/meter at the 100m
range?
Options ------------------------------------------------------
Yes - No
Default Selection --------------------------------------------
Yes

Message Text -------------------------------------------------
SeaScan PC is using a  single frequency towfish.  The single frequency
has been recorded as 300 kHz.
Options ------------------------------------------------------
Ok - Cancel
Default Selection --------------------------------------------
Ok
```

Figure 10: REMUS Sample Log

6.5. Single Beam Echo Sounder

It was hypothesized, early in the testing program, that a low frequency single beam echosounder might be used to discriminate between high impedance objects and low impedance clutter by generating refraction patterns around the harder objects.

An Odom 12 kHz system was used to test this theory. The system was configured to look sideways at about 45º from nadir. As shown in Figure 11, the echosounder had very limited functionality when deployed as a side looking device. Under optimal conditions it may have located a few of the targets. Additionally, what little signature that was evident in the target range was overwhelmed by returns in wooded terrain, as seen in Figure 12.

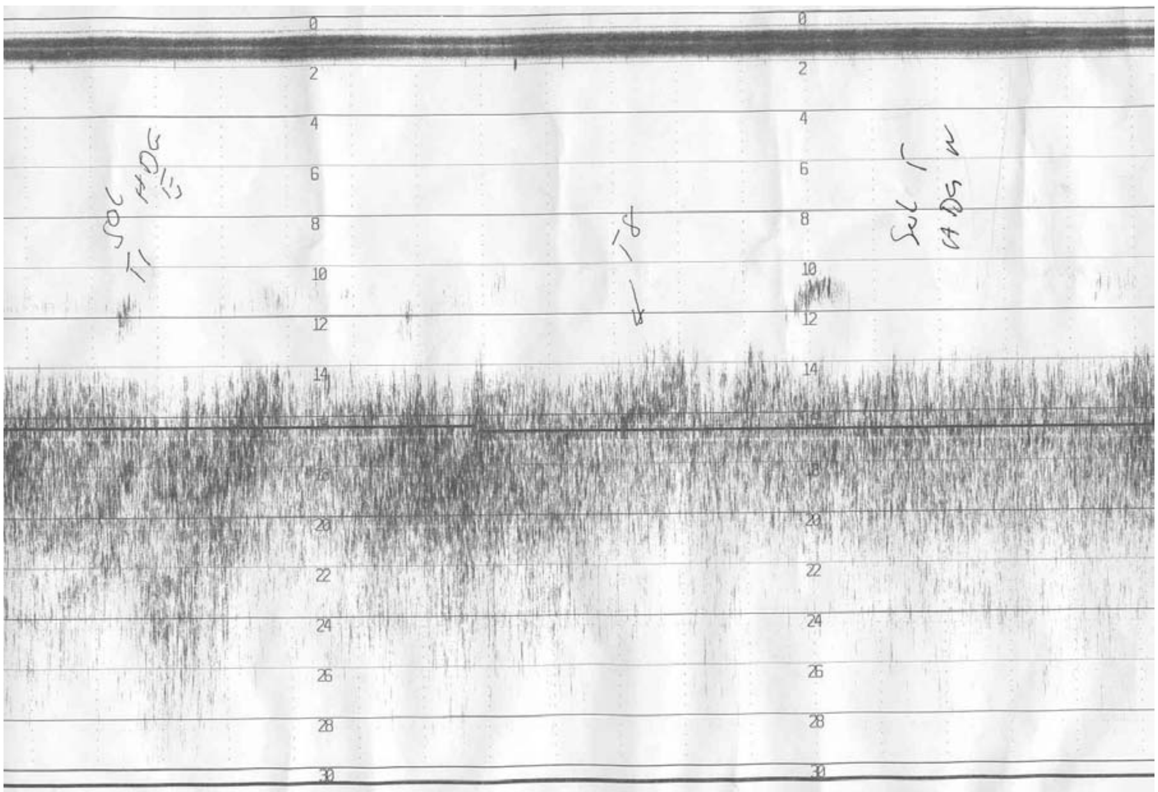


Figure 11: 12kHz echosounder in TR1

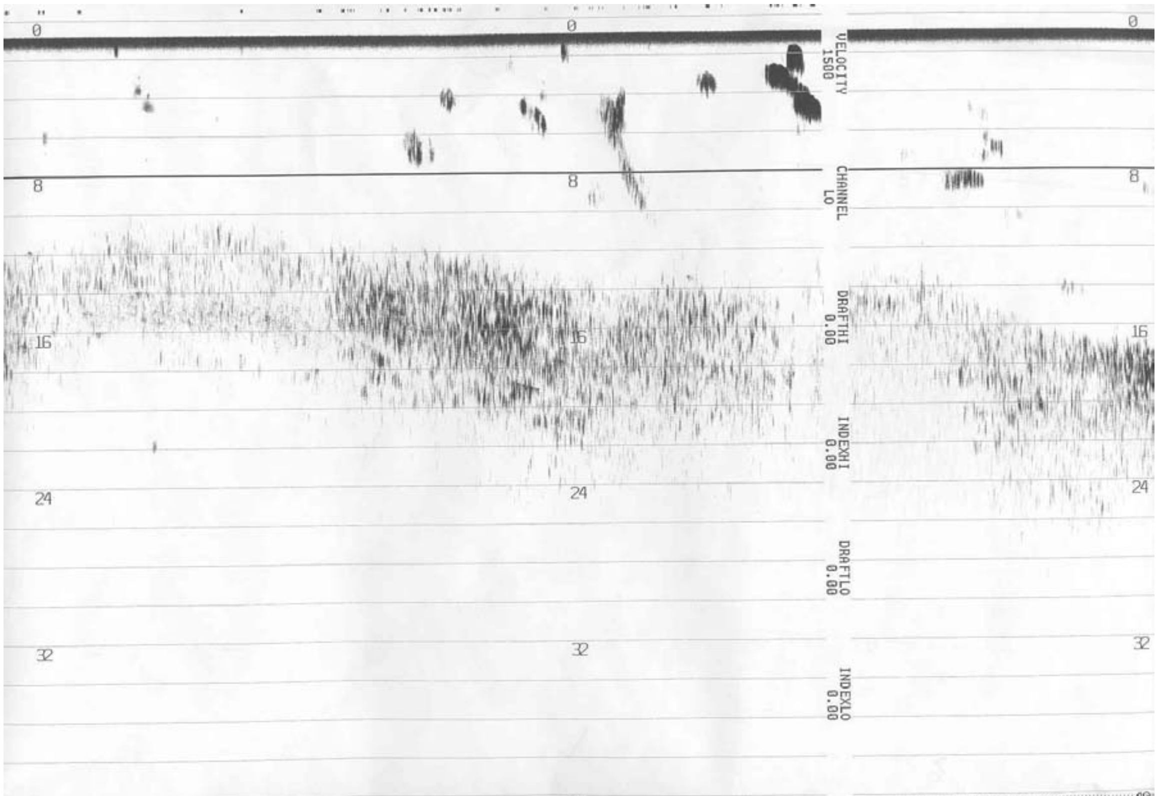


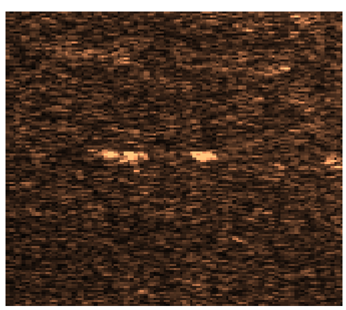
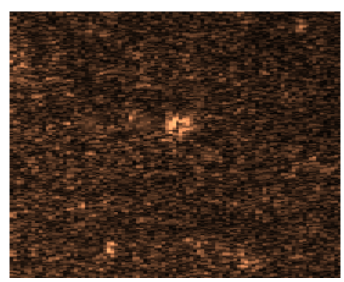
Figure 12: 12kHx echosounder in wooded terrain

Direct comparison of Sonar results

Test range results for each sonar are compared, side-by-side. Any apparent advantages of particular systems are noted and discussed.

6.6. Test Range 1

Table 18: TR1 reflector 1 comparison

Reflector 1 SS Tail Fins in water column Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000	Edgetech MPX

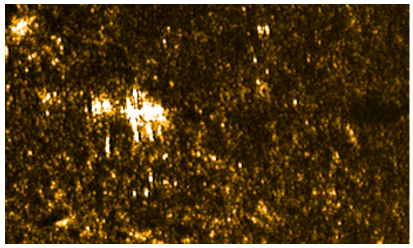
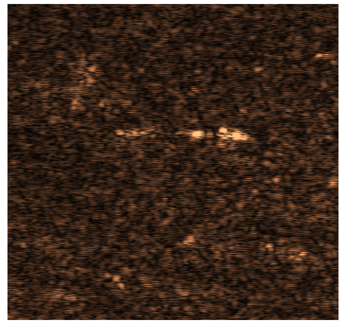
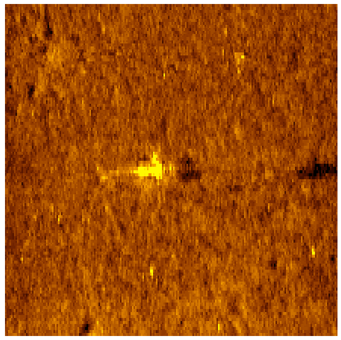
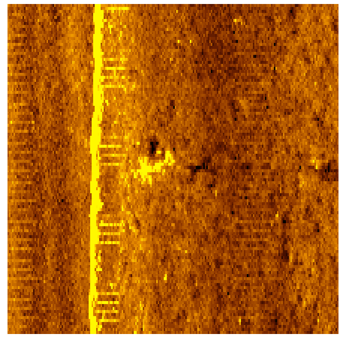
		
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

Table 19: TR1 Target 1 comparison

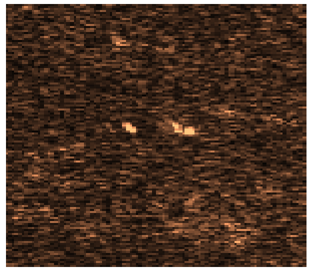
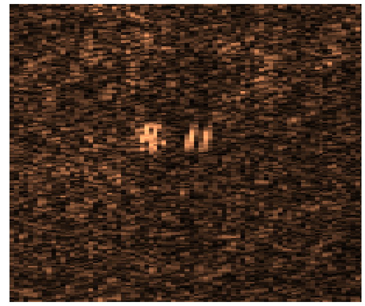
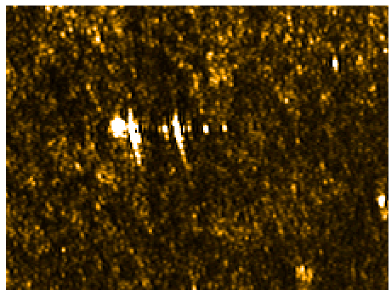
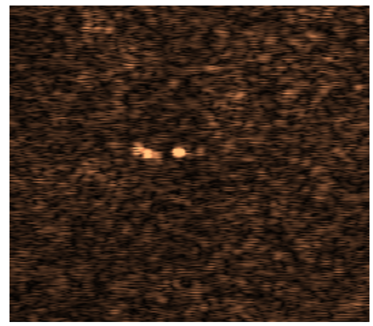
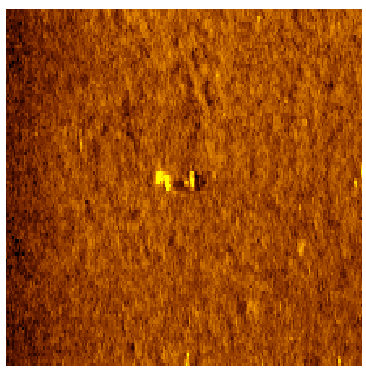
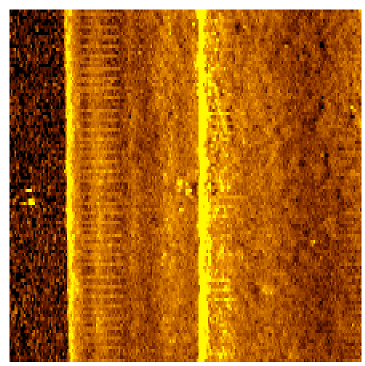
Target 1 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000 	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

Table 20: TR1 Target 2 comparison

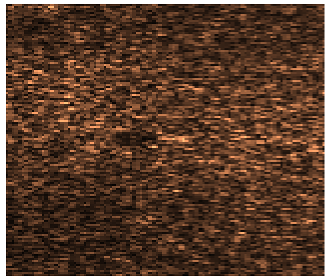
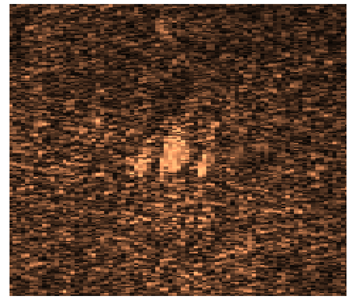
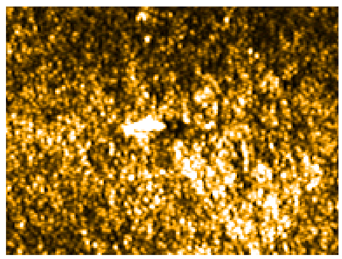
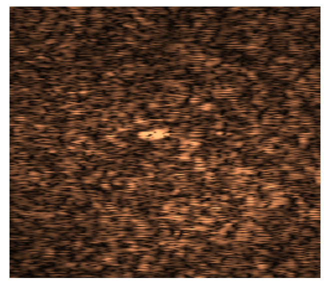
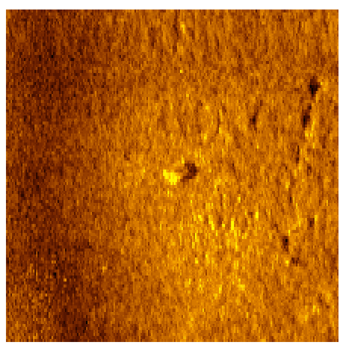
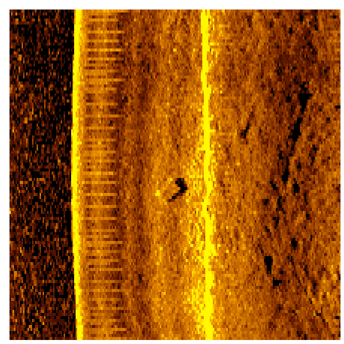
Target 2 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000 	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

Table 21: TR1 Target 3 comparison

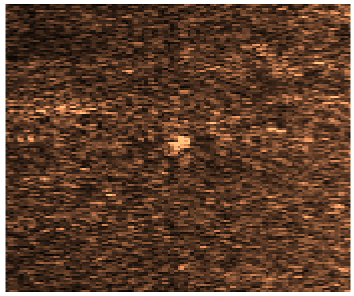
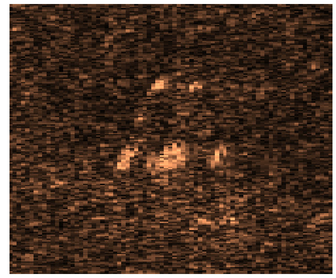
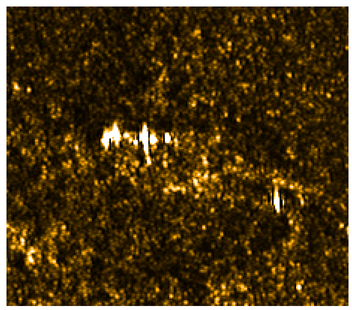
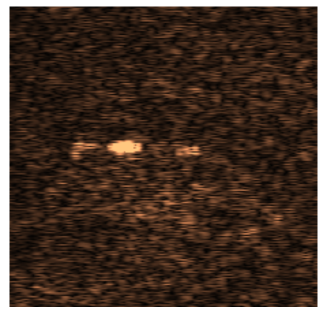
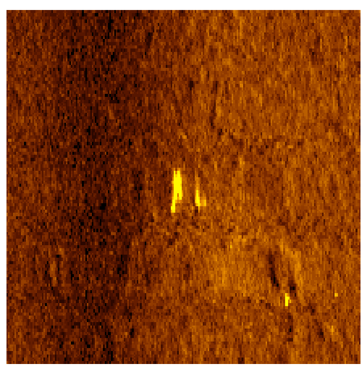
Target 3 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000 	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS

Table 22: TR1 Target 4 comparison

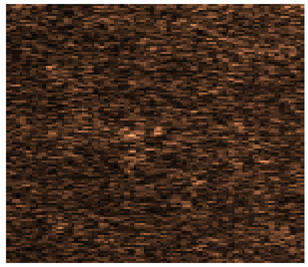
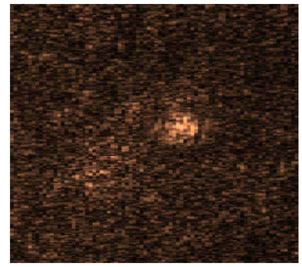
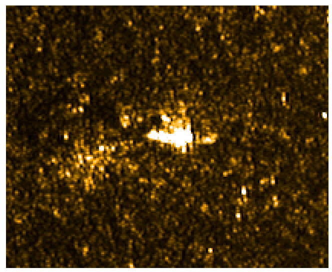
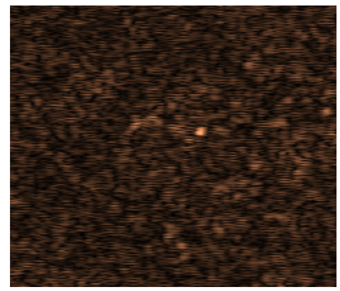
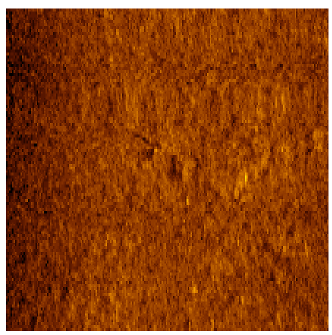
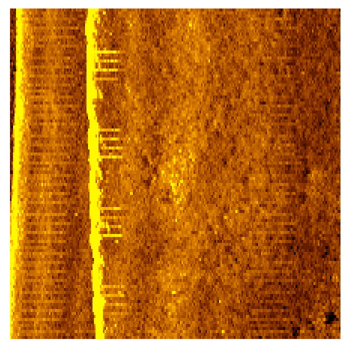
Target 4 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000 	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

Table 24: TR1 Target 6 comparison

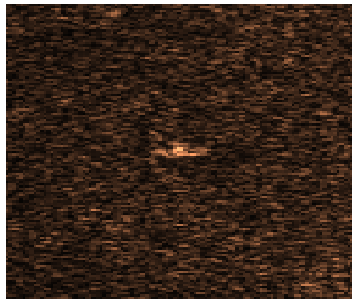
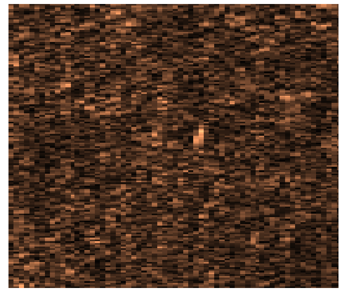
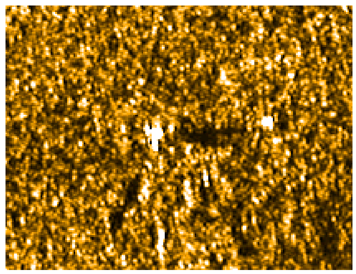
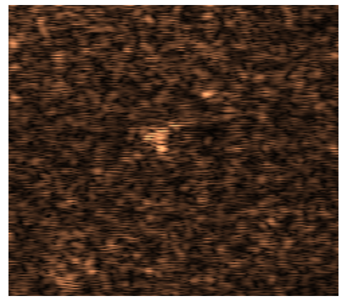
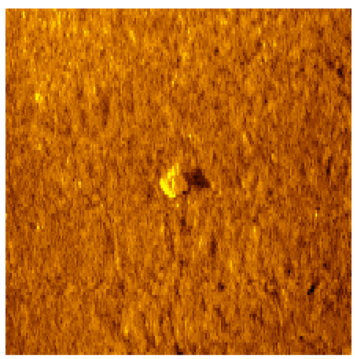
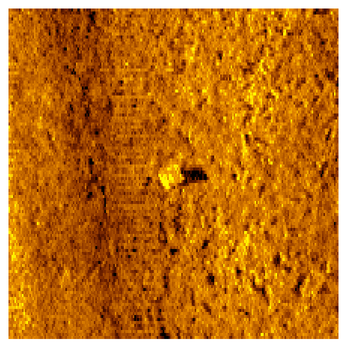
Target 6 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000 	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

Table 23: TR1 Target 5 comparison

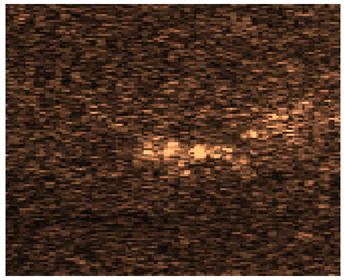
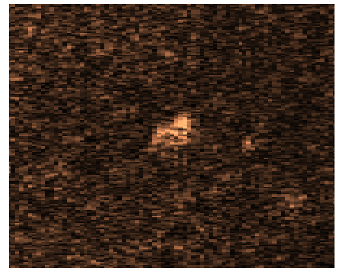
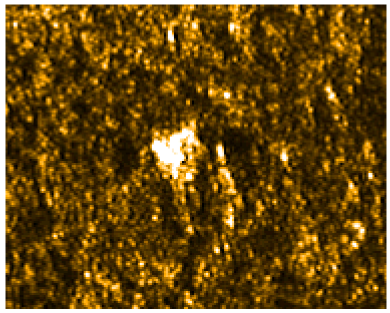
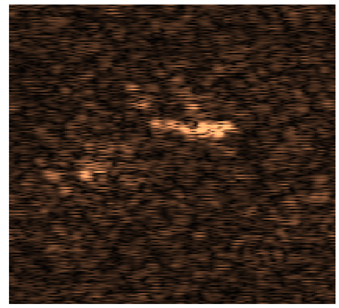
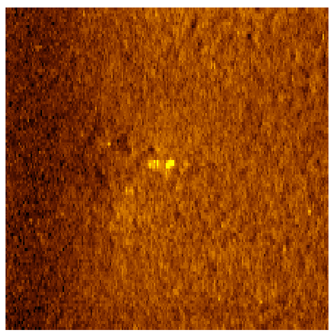
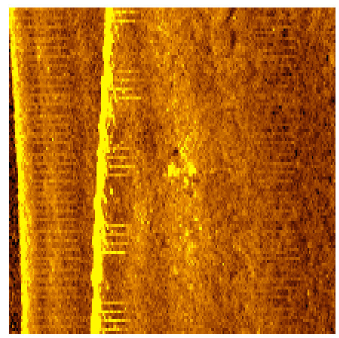
Target 5 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000 	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

Table 25: TR1 Target 7 comparison

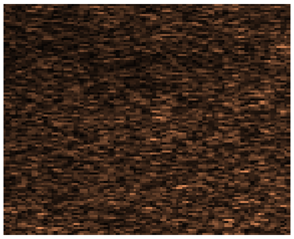
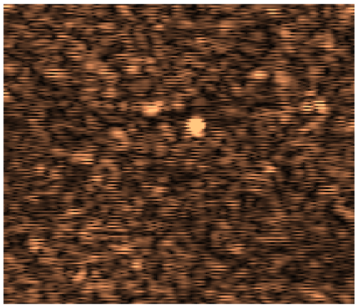
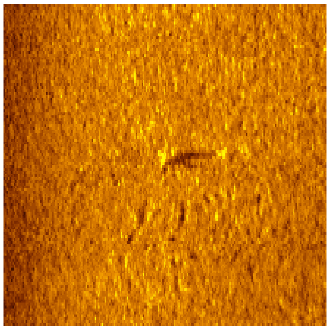
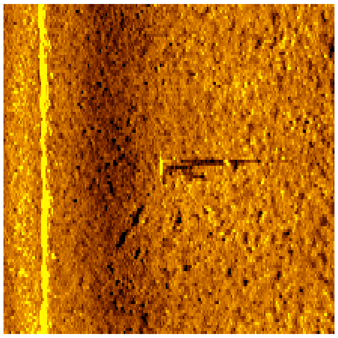
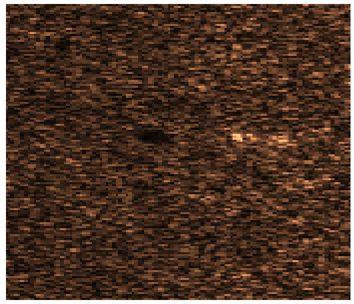
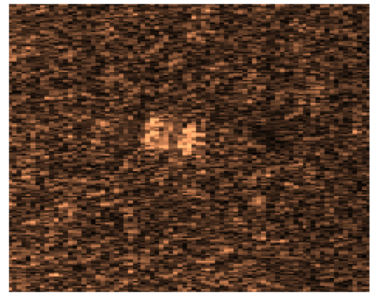
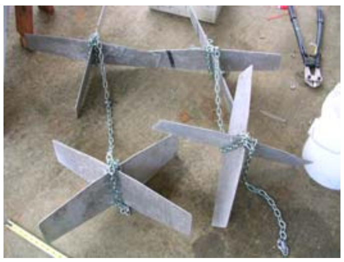
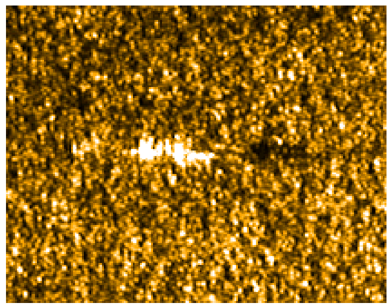
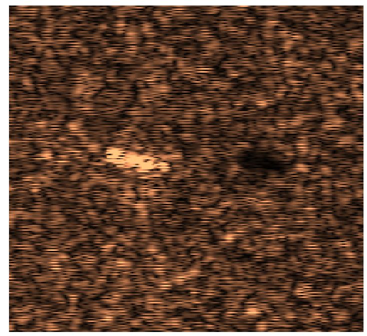
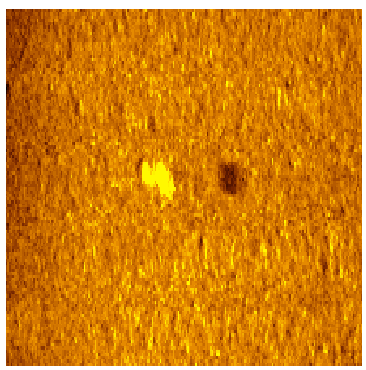
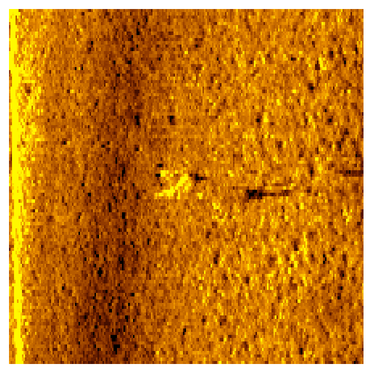
Target 7 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101
	Klein 3000	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

Table 26: TR1 Reflector 2 comparison

Reflector 2 Old tire Clear terrain 10m depth	Reson 8125 	Reson 8101 
	Klein 3000 	Edgetech MPX 
Marine Sonic Stock	Marine Sonic Custom 	Marine Sonic REMUS 

6.7. Test Range 2

Table 27: TR2 Reflector 1 comparison

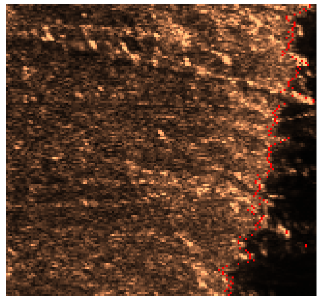
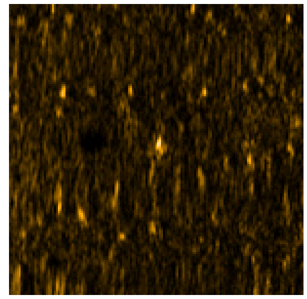
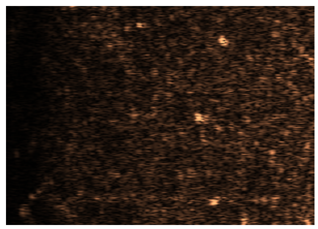
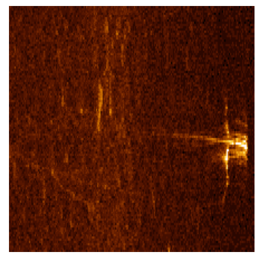
Reflector 1 Buoy on bottom Clear terrain 17.5m depth	Reson 8125 	Klein 3000 
	EdgeTech MPX 	Marine Sonic (900kHz) 

Table 28: TR2 Target 1 comparison

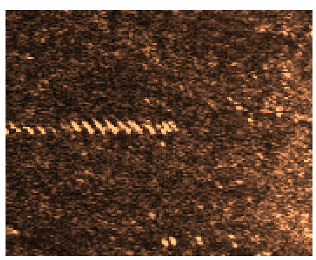
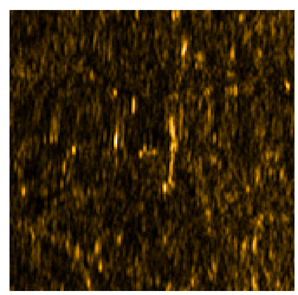
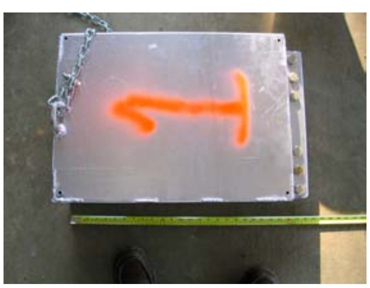
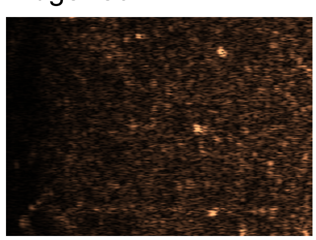
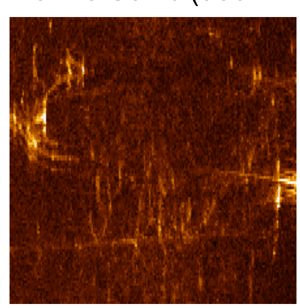
Target 1 OEX mock-up Clear terrain 18m depth	Reson 8125 	Klein 3000 
	EdgeTech MPX 	Marine Sonic (900kHz) 

Table 29: TR2 Target 2 comparison

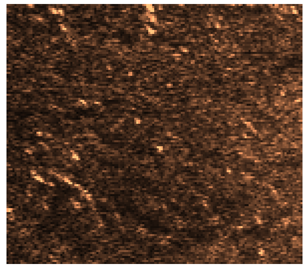
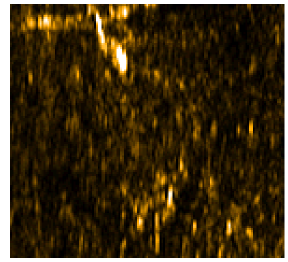
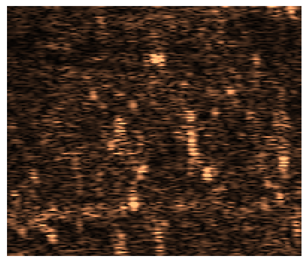
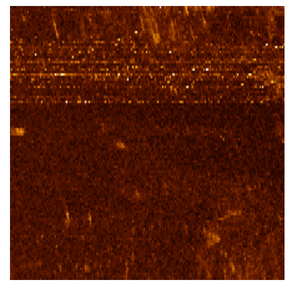
Target 2 PC case Wooded terrain 18m depth	Reson 8125 	Klein 3000 
	EdgeTech MPX 	Marine Sonic (900kHz) 

Table 30: TR2 Target 3 comparison

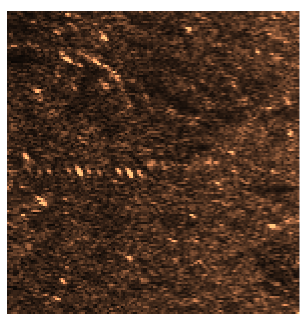
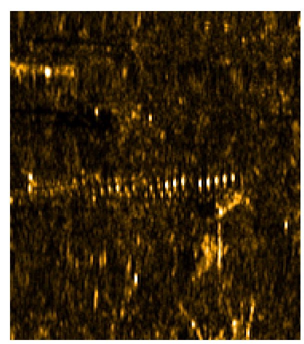
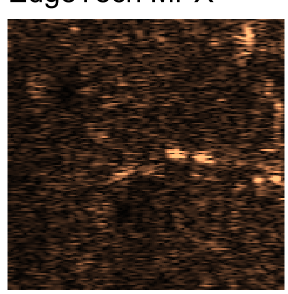
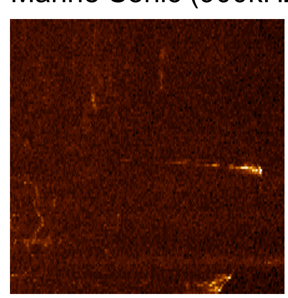
Target 3 OEX mock-up Wooded terrain 18.5m depth	Reson 8125 	Klein 3000 
	EdgeTech MPX 	Marine Sonic (900kHz) 

Table 31: TR2 Target 4 comparison

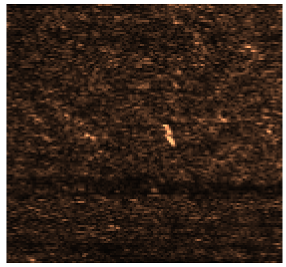
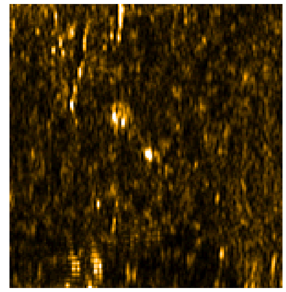
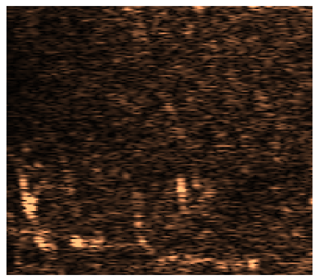
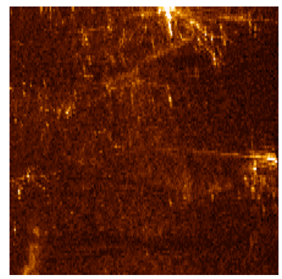
Target 4 PC Case Wooded terrain 18.5m depth	Reson 8125 	Klein 3000 
	EdgeTech MPX 	Marine Sonic (900kHz) 

Table 32: TR2 Target 5 comparison

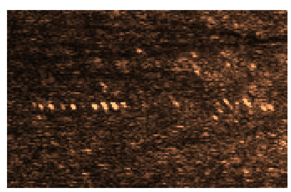
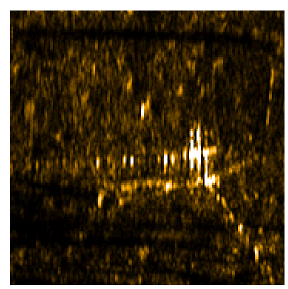
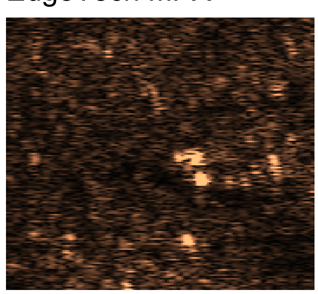
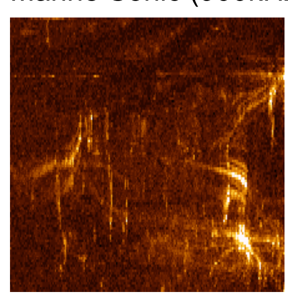
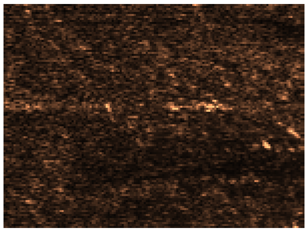
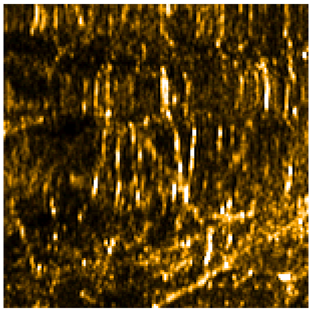
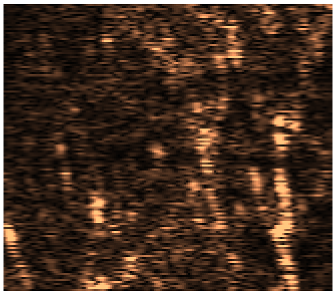
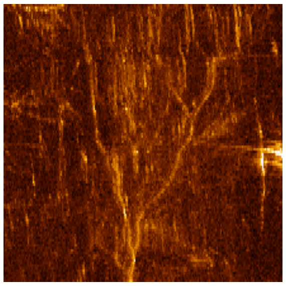
Target 5 OEX mock-up Wooded terrain 18.5m depth	Reson 8125 	Klein 3000 
	EdgeTech MPX 	Marine Sonic (900kHz) 

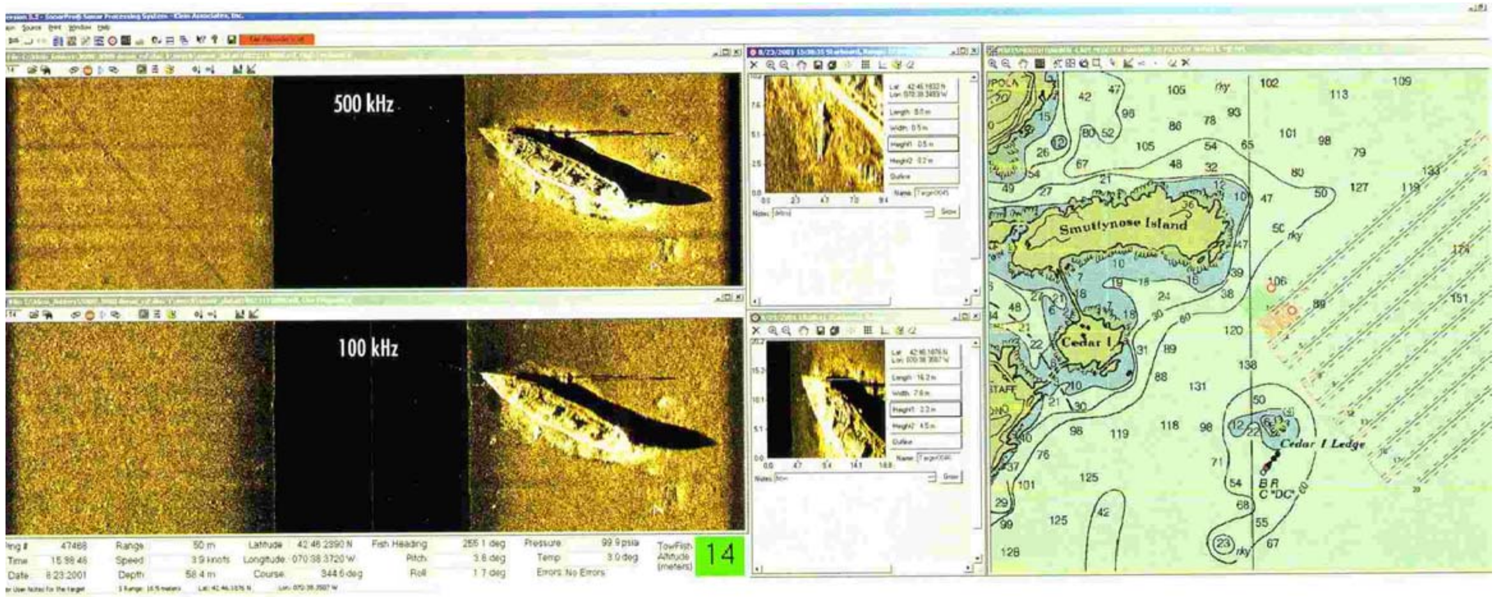
Table 33: TR2 Reflector 2 comparison

Reflector 2 Buoy on bottom Wooded terrain 18.5m depth	Reson 8125 	Klein 3000 
	EdgeTech MPX 	Marine Sonic (900kHz) 

Appendices

1- Hardware Descriptions

   a. Manufacturers descriptions of tested sonars.



SPECIFICATIONS

Towfish

Frequencies	100 kHz (125 kHz +/- 1% act.), 500 kHz (445 kHz, +/- 1% act.)
Transmission Pulse	Tone Burst, operator selectable from 25 to 400 μsecs.
	Independent pulses for each frequency
Beams	Horizontal - 1 deg. @ 100 kHz, 0.2 deg. @ 500 kHz
	Vertical - 40 deg.
Beam Tilt	0, 10, 20 degrees, adjustable
Maximum Range	450 meters @ 100 kHz; 150 meters @ 500 kHz
Depth Rating	1,500 meters standard, options to 3km & 6km depths
Construction	Stainless Steel
Size	122 cm long, 8.9 cm diameter
Weight	29 kg in air
Options	Sub-Bottom Profiler, Magnetometer
	Attitude Sensors: roll, pitch, heading, pressure, attitude
	Acoustic Positioning Responder
	Single frequency of 50 kHz

Transceiver Processor Unit (TPU)

Operating System	VX Works™ with custom application
Basic Hardware	19-inch rack or table mount, VME bus structure
Outputs	100 Base-Tx, Ethernet LAN
Navigation Input	NMEA 0183
Power	120 watts @ 120/240 VAC, 50/60 Hz

Klein Sonar Workstation

Basic Operating System	Windows NT & 2000 or equiv.
Sonar Software	SonarPro™
Data Storage	Internal hard drive, optional devices available
Hardware	Industrial PC with technically advanced components

Tow Cables

Klein offers a selection of coaxial, Kevlar reinforced, lightweight cables, double armored steel cables, and interfaces to fiber optic cables. All cables come fully terminated at the towfish end.

KLEIN

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SonarPro™ Software

Custom developed software by users and for users of Klein side scan sonar systems operating on Windows NT & 2000. Field proven for many years on Klein's Multi-Beam Focused Sonar Series 5000 Systems and adapted to the System 3000 single-beam system. SonarPro™ is a modular package combining ease of use with advanced sonar features.

Basic Modules	Main Program, Data Display, Information, Target Management, Navigation, Data Recording & Playing, and Sensor Display.
Multiple Display Windows	Permits multiple windows to view different features as well as targets in real time or in playback modes. Multi-Windows for sonar channels, navigation, sensors, status monitors, targets, etc.
Survey Design	Quick & easy survey set up with ability to change parameters, set tolerances, monitor actual coverage, and store settings.
Target Management	Independent windows permitting mensuration, logging, comparisons, filing, classification, positioning, time & survey target layers, and feature enhancements. Locates target in navigation window.
Sensor Window	Displays all sensors in several formats (includes some alarms) and responder set up to suit many frequencies and ping rates.
Networking	Permits multiple, real time processing workstations via a LAN including "master and slave" configurations.
"Wizards"	To help operator set up various manual and default parameters.

SeaBat 8101 PRODUCT SPECIFICATION

240kHz MULTIBEAM ECHO SOUNDER

- Phase and Amplitude Bottom Detection
- 150° Wide Swath Coverage
- 240 kHz Frequency
- Up to 500m Range Capability
- Portable Configuration
- Meets USACE Class 1 Standards
- Meets IHO Standards

The SeaBat 8101 Multibeam Echo Sounder measures discrete depths, enabling complex underwater features to be mapped with precision. Dense coverage is achieved utilizing up to 3,000 soundings per second for a swath that can be over 500 meters wide, even as the survey vessel travels at speeds of over 18 knots.

With high accuracy and a measurement rate up to 30 profiles per second, the SeaBat 8101 enables surveys to be completed faster and in greater detail than previously realized. The SeaBat is an integral part of the new, integrated bathymetry surveying systems.

The SeaBat transducer is available pressurized for depths from 100 to over 3,000 meters. Small and lightweight, it can be can be mounted on small un vehicles (ROV, AUV or towed) and taken to where accurate measure required.

RESON

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http://www.reson.com

SeaBat 8101 Built-In Test Environment ("BITE") Screen

SYSTEM SPECIFICATIONS

Operating Frequency:	240kHz
Range Scales:	5, 10, 15, 20, 25, 35, 50, 75, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500m.
Range Resolution:	1.25 cm
Number of Beams:	101
Horizontal Beamwidth:	1.5°
Horizontal Coverage:	150°
Vertical Beamwidth:	1.5°
Update Rate:	Range-variable up to 30 times per second

SONAR HEAD SPECIFICATIONS

Power Requirement:	24VDC, 2 Amps max. (Power available from surface processor.)
Uplink:	Digital, 76.8 Mbaud
Down Link Control:	RS-232 or RS-422, 19,200 baud
Operating Depth:	100 meters (300m, 1500m, 3000m & 6000m avbl.)
Dimensions:	266x320mm W/Diam (does not include projector)
Temperature:	Operating: -5° to +40°C Storage: -30° to +55°C
Weight (aluminum):	Dry: 26.8 kg (59 lbs) Wet: 4.8 kg (10.6 lbs)
Weight (titanium):	Dry: 40 kg (88 lbs) Wet: 18 kg (39.6 lbs)

DISPLAY SPECIFICATIONS

Screen Size:	14 inch Diagonal
Input:	SVGA (800x600, 72 Hz)
Display:	High Resolution Color
Power Consumption:	62 W

PROCESSOR SPECIFICATIONS

Power Requirements:	115/230VAC, 50/60Hz, 100W max.
Data Output:	Selectable, 300-155.2 Kbaud or Ethernet 10 base T or 10 base 2
Video Output:	SVGA (800x600, 72 Hz) or NTSC or PAL video.
Graphics Colors:	256 colors (8-bit)
Display Mode:	Sector Format
Display Arc:	150°
Input Device:	3-Button Trackball
Dimensions:	19" rack, 4U high (266x483x434mm HWD)
Temperature:	Operating: 0° to +40°C Storage: -30° to +55°C
Weight:	20 kg (44 lbs)

SeaBat 8101 Head with Optional Fairings

OPTIONS

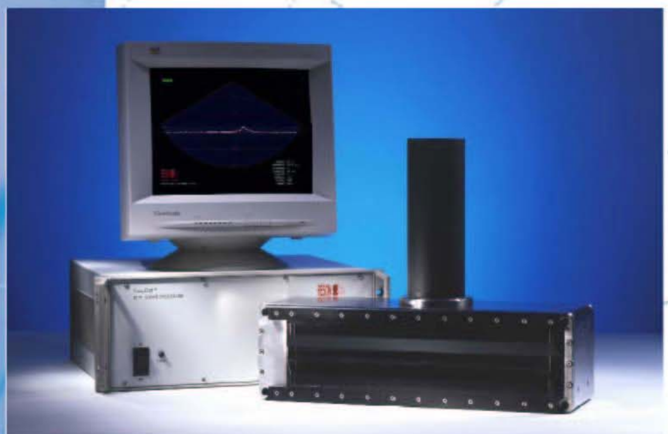
Option 033:	Side Scan Upgrade
Option 034:	Mounting Plate Assembly
Option 035:	Fairings (pictured above)
Option 036:	Spares Kit
Option 037:	Titanium Housing
Option 038:	210° Swath
Option 040:	Extended-Range Projector
Option 049:	Increase Transducer Depth Rating

Version 4.0
032399

RESON

Due to our policy of continuous product improvement, specifications are subject to change without notice.

SeaBat 8125
PRODUCT SPECIFICATION
ULTRA HIGH RESOLUTION FOCUSED MULTIBEAM ECHOSOUNDER SYSTEM



- Focused 0.5° beams
- 240 beams
- 2.5 cm near field resolution
- 6 mm depth resolution
- 120° swath coverage

The SeaBat 8125 is the first wide-sector, wide-band, focused multibeam sonar ever to be deployed. Utilizing 240 dynamically focused receive beams, the system measures a 120° swath across the seafloor, detects the bottom, and delivers the measured ranges at a depth resolution of 6 mm. The backscatter intensity image is displayed in real time on the sonar display.

The 8125 can be controlled through its native graphical user interface, or through an external control like the 6042 data collection and navigation software package.

The system can be mounted on a survey vessel or deployed on an ROV at depths down to 1500 m. The high-speed data uplink is carried on a standard SeaBat copper cable for surface installation. A fiber-optical interface is available for ROV deployment.

Two 8125 systems can be configured as a dual-headed system, with Option 011, and for complete control the 6043 image fusion and controller merges the images of the two sonar heads into one.

RESON

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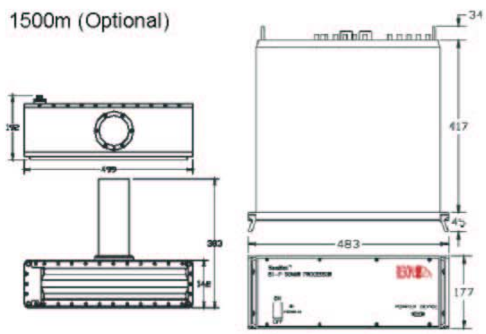
SeaBat 8125 SYSTEM SPECIFICATIONS

SYSTEM PERFORMANCE

Frequency:	455 kHz
Depth Resolution:	6 mm
Swath Coverage:	120°
Max Range:	120 m
Number of Beams:	240
Along-Track Beamwidth:	1°
Across-Track Beamwidth:	0.5°
Accuracy:	• IHO Special Order • U.S. Army Corps of Engineers Special Order
Operational Speed:	Up to 12 knots
Max. Update Rate:	40
Transducer Depth Rating:	600m (Standard)

1500m (Optional)



Dimensions are in mm

INTERFACE

System Supply:	115V/230V 50/60 Hz, 350W max
Video Display:	SVGA, 800 x 600, 72 Hz
System Control:	Trackball or from Ethernet
Data Output:	10 MB Ethernet or serial RS232C
Data Uplink:	High-speed digital coax with fiber-optic option
Sonar Head Supply:	24V, 4A (from ROV or sonar processor)
Temperature:	Operating: 0° to +40° C Storage: -30° to +55° C

MECHANICAL INTERFACE

Dimensions (HWD):	
Sonar head:	192 x 499 x 383 (depth includes projector)
Processor:	177 x 483 x 417
Transducer Weight:	
600m aluminum version:	24.3 kg (dry) 8.6 kg (wet)
1500m titanium version:	35.2 kg (dry) 19.1 kg (wet)
Processor Weight:	20 kg

RESON

Version: B23-PDF-0110

Due to our policy of continuous product improvement, RESON reserves the right to change specifications without notice.

MP-X *MultiPulse Side Scan Sonar System*

"The industry's first affordable high speed, high resolution, side scan sonar system."

The **EdgeTech MP-X MultiPulse Side Scan Sonar** represents a ground-breaking advancement in side scan sonars.

Conventional side scan sonars have always been defined by the limitation of having only one ping in the water at a time. Typically this has kept the speed of survey below 5 knots to ensure 100% coverage. Until now, the only method for conducting faster surveys has been multibeam side scans – products that are severely limited by cost and complexity.

Innovation and Simplicity

Based on EdgeTech's Full Spectrum Frequency Modulated (FM) pulses, the MP-X uses proprietary signal coding to place up to 4 pulses in the water at the same time. This translates into a **4 times** increase in survey speeds while still maintaining 100% bottom coverage or a **4 times** increase in hits on the target for improved imaging at standard survey speeds. All of this with the simplicity and cost of a conventional single beam side scan system!

Improved Resolution

To improve resolution at range, EdgeTech has developed Dynamic Aperture Processing™ (DAP) for use on the MP-X. DAP reduces beam width at the maximum range of the sonar by over 40%, thus increasing the range at which a 1 meter target can be typically detected by over 60%.

Discover the Difference!

Features:

- High speed data collection at up to 16 knots
- Enhanced resolution at range using Dynamic Aperture Processing™ (DAP)
- Flexible system design allows for operation from shallow water to full ocean depth

Applications:

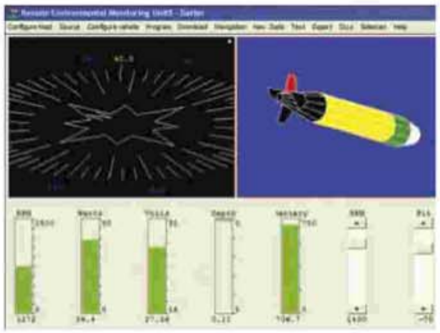
- Hydrographic surveys
- Geophysical surveys
- Cable and pipeline surveys
- Search and recovery
- Mine counter measure surveys
- Site selection surveys, pre-/post dredging surveys

EdgeTech
FULL SPECTRUM® SONAR SYSTEMS

REMUS has arrived! After years of development at the Woods Hole Oceanographic Institute (WHOI), the world's most powerful, compact AUV is now commercially available only through Hydroid, Inc.

REMUS (Remote Environmental Monitoring Units) is the culmination of years of leading edge research and development, combined with a proven track record for highly reliable and repeatable field operations.

REMUS's capabilities make it ideally suited for scientific, commercial and/or military operations. The vehicle is small enough to be carried by one man, yet contains enough sophisticated sensor, navigation, and power resources to enable it to perform intricate sonar and oceanographic surveys over large areas.



REMUS FEATURES:

Compact Size & Weight: REMUS's compact size allows for economical overnight shipping and one-man deployment and operation capability. REMUS also eliminates the need for larger vessels and costly special handling equipment.

Proven Reliability: With a track record second to none, REMUS is the only compact AUV to be selected by the U.S. Navy Fleet for their mine counter measure operations. The system boasts over five years of continuous product development and thousands of hours of field operations.

Ease of Operation: An intuitive graphical user interface allows anyone to become an AUV operator with just a few hours of training.

Powerful & Versatile: REMUS contains a full suite of standard sensors, with new sensors being integrated on a continuous basis. In its standard configuration, REMUS collects the following data:

- Acoustic Doppler Current Profiling (ADCP)
- Navigation data including: Long Base Line (LBL), Ultra Short Base Line (USBL), and Dead Reckoning accuracies
- Side scan sonar
- Optical backscatter
- Heading, roll and pitch
- Mission progress
- Conductivity and Temperature
- Bathymetry
- Sound speed
- System status

REMUS is the ideal tool for:

- Hydrographic surveys
- Harbor security operations
- Debris field mapping
- Fishery operations
- Mine counter measure operations
- Environmental monitoring
- Search and salvage operations
- Scientific sampling and mapping

REMUS Specifications

VEHICLE DIAMETER 19 cm

VEHICLE LENGTH 160 cm

WEIGHT IN AIR 37 kg (<80 pounds)

TRIM WEIGHT 1 kg

MAXIMUM OPERATING DEPTH 100 meters

ENERGY 1 kw-hr internally rechargeable Lithium ion

ENDURANCE 22 hours at optimum speed of 1.5 m/s (3 knots)
>8 hours at 2.5 m/s (5 knots)

PROPULSION Direct drive DC brushless motor to open 3-bladed propeller

VELOCITY RANGE 0.25 to 2.8 m/s variable over range

CONTROL 2 coupled yaw and pitch fins

ON/OFF Magnetic switch

EXTERNAL HOOK-UP 2-pin combined Ethernet, vehicle power and battery charging. 4-pin serial connector

NAVIGATION Long base line; Ultra short base line; Doppler-assisted dead reckoning

TRANSPONDERS 20–30 kHz operating frequency range

TRACKING Emergency transponder, mission abort, and ORE Trackpoint compatible

SENSOR Doppler Velocity Log
Side Scan Sonar
Light Scattering Sensor
Conductivity & Temperature

SOFTWARE GUI-based laptop interface for programming, training, post-mission analysis, documentation, maintenance and troubleshooting

DATA EXPORTING AND REPORTING HTML report generator, direct Matlab and ASCII text export

SHIPPING 2 reusable cases for all equipment, each less than 150 lbs (suitable for Fed-Ex transport)

HYDROID

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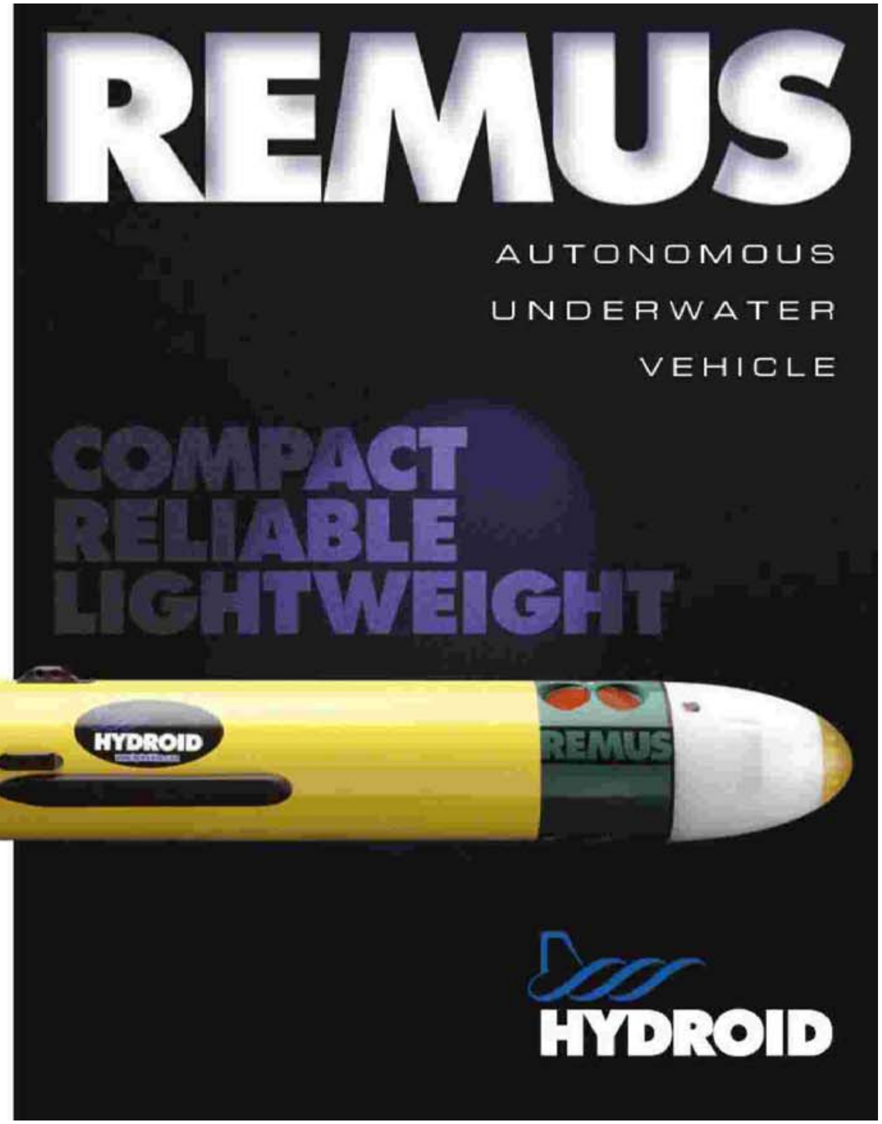
Tel: 508-457-9191 • Fax 508-457-6622
E-mail: sales@hydroidinc.com
www.hydroidinc.com



FULL SPECTRUM® SONAR SYSTEMS

MP-X MultiPulse Side Scan Sonar

Tow Vehicle

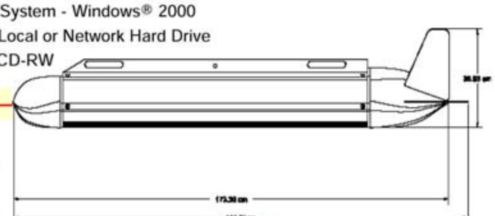
Frequency:		270 kHz	410 kHz
Pulse Type:		Full Spectrum FM	Full Spectrum FM
No. of Pulses:		4	4
Towing Speed @ 100 M Range Scale:[1]		up to 8 / 16 knots	up to 8 / 16 knots
Maximum Operating Range:		225 meters per side (450 meter swath)	115 meters per side (230 meter swath)
Maximum Operating Depth:[2]		300 meters	300 meters
Pulse Repetition Rate:		14 / 28 @ 100 meters	14 / 28 @ 100 meters
Horizontal Beam Width:		0.75 M @ 100 meters 1.25 M @ 200 meters	0.35 M @ 50 meters 0.5 M @ 100 meters
Resolution Across Track:		0.075 / 0.15 meters	0.05 / .03 meters
Towfish TVG:		none required	none required
Physical:	Length:	(L) 173 cm x (H) 37 cm	(L) 173 cm x (H) 37 cm
	Diameter:	19 cm	19 cm
	Weight (in air):	60 kg	60 kg
	Weight (in water):	20 kg	20 kg

Telemetry

Link:		MultiMux Option	StarMux Option
Trigger for USBL:		TTL	TTL
Tow Cable:	Type:	6 conductors	11 mm coax
	Maximum Length:	350 meters	6000 meters

Sonar Control and Display Processor

Data Output:	100 Base T Ethernet
Data Formats:	EdgeTech Full Spectrum (JSF), XTF to disk, others formats on request
Navigation Input:	NMEA 0183
Range Scale Settings:	25, 50, 75, 100, 150, 200, 250
Thermal Printers Supported:	EPC, Ultra, Raytheon (data can be sub-sampled to match printer speed)
Annotation:	Keyboard, RS232
Event Marks:	Manual, Internal Timed
Computer:	Processor - Ruggedized PC Operating System - Windows® 2000
Mass Storage	Primary – Local or Network Hard Drive Archive – CD-RW



System Power

Power - Sonar Control & Display Processor Stand Alone or w/ StarMux Telemetry Option:	200 watts
Power - Sonar Control & Display Processor w/ MultiMux Telemetry:	300 watts
System Voltage:	115/230 50/60 Hz Auto-Sensing

Notes:

[1] Meets NOAA Shallow Water Survey specification – minimum 3 pings on a 1 meter target.
[2] Other depth ratings available

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The anatomy of autonomy.
Operating Life: 1 KW hr lithium ion battery for up to 20 hours of continuous operation.
Navigation Transponders: Four small, lightweight transponders are supplied as reference beacons for the vehicle during operation. The transponders are preset to listen for a specific signal, which is transmitted by the vehicle, and then immediately reply. The vehicle may then easily compute the slant range to the transponder.
Acoustic Doppler Current Profiler (ADCP)/Doppler Velocity Log (DVL): The specially designed RD Instruments ADCP/DVL can be configured to include both downward and upward looking transducers, allowing for bi-directional current profiling, 3-D bottom track, altitude measurement and highly accurate dead reckoning navigation input. The altitude measurement, when coupled with the vehicle's position and depth, also provides seafloor bathymetry.
Conductivity and Temperature: The vehicle is equipped with a multi-parameter sensor sonde, which includes temperature and conductivity. Temperature information is stored in the REMUS hard drive for plotting a profile of the water temperature in the search area. Conductivity and temperature inputs are used to accurately determine the speed of sound in water, which is used to increase navigational accuracy.
Side Scan Sonar: 600, 900 or 1200 kHz side scan sonar designed specifically for the demanding AUV environment. The compact, light weight design incorporates the same proven technology found in traditional towed configurations.
100 M depth rating
Chemical Light Bracket for night time operation
Operating speed from 3 to 5 knots
HYDROID
REMUS
Light Scattering Sensor: The vehicle contains a lightweight, low power optical sensor that provides important information about the optical properties of the ocean. This data is especially useful to support diving, environmental, or optical imaging operations.
Magnetic on/off switch
Acoustic Transducer and Cable: Portable low-drag transducer transmits and receives wideband signals from the vehicle and transponders to the Ranger unit.
Navigation: REMUS navigates during a mission using three methods: Long Baseline (LBL), Dead Reckoning (DR) and Ultra-Short Baseline (USBL). The on-board computer automatically determines the preferred method, and can vary it throughout the mission.
Power/Data Interface Module: This module serves as an external power supply to recharge the Li-Ion batteries and to preserve the batteries when conducting on shore testing. It also provides a high-speed communications link to the vehicle, allowing data to be downloaded to one or more computers.
REMUS Ranger: The REMUS vehicle carries an emergency transponder, completely independent of the vehicle's other systems that may be interrogated at any time. The Ranger is a small, waterproof deck unit, designed to give the operator the ability to monitor the vehicles progress via this transponder while the mission is underway. The Ranger consists of a highly portable deck unit connected to a small, towed transducer. The front panel display indicates the real-time range to the vehicle in meters and/or is used to send selected commands such as "abort mission" or "come home" to the vehicle during operation.
Ruggedized Laptop Computer includes intuitive graphical user interface designed for simple pre-launch checkout, mission planning, and data reporting.

CENTUTION$_{TM}$ Splash Proof

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White Marsh, VA 23183

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AUV and ROV System

Sea Scan® PC Side Scan Sonar System Information/Specifications Sheet

GENERAL

Sea Scan® PC is a high-resolution side scan sonar system designed to locate large and small objects underwater as well as display bottom information used for biological research and survey operations. The system provides a near photographic sonic image, regardless of underwater visibility, and employs a state of the art personal computer (PC) for all control, display, analysis and storage functions. This sheet provides operating information and system specifications for all systems manufactured by Marine Sonic Technology, Ltd. (MSTL).

MSTL manufactures the Sea Scan® PC as a Towed System, AUV/ROV System, Submerged System, and as a combination Sea Scan® PC system and Geometrics Magnetometer known as the MagScan®. In addition, MSTL is a leader in custom side scan sonar applications, working with customers to meet their unique and demanding custom installations.

The towed system is MSTL's basic and most popular system. It is available in several different models with each providing near picture quality images, ease of operation, a powerful software package, dependability and affordability. MSTL also offers the Sea Scan® PC system components miniaturized for AUV/ROV applications. The system's electronics card is available as an ISA or PC104 card and the single and dual frequency transducers have been streamlined and miniaturized for AUV/ROV applications.

Two additional and unique side scan sonar systems produced by MSTL are the Submerged System (non-towed) and the MagScan® System (towed). The Submerged System was designed and developed to meet the requirements for a side scan sonar system, which could be operated underwater. A diver inside a wet underwater vehicle can easily operate the system.

FIELDWORKS Portable System

Submerged System

The second unique system is the MagScan ○, which is manufactured in conjunction with Geometrics®, Inc. This system combines, in one towfish, the Sea Scan® PC system and the Geometrics® G-880 magnetometer. This unique combination allows for collection and display of real time sonar images and magnetometer data on the same screen.

Sea Scan® PC systems are used worldwide by law enforcement agencies including the U.S. Customs Service, state and city police departments, sheriffs departments, fire departments, dive teams and naval military forces. Additional Sea Scan® PC systems are employed by treasure hunters, oil companies, diving and salvage companies, survey companies, and major universities for archaeological and biological research.

MSTL has designed and manufactured custom configurations to meet unique customer needs. Some special configurations completed are:

- U.S. Customs Service for detecting illegal drug shipments.
- Woods Hole Oceanographic Institution for use in autonomous underwater vehicle (AUV) research.
- Submerged system for wet underwater manned operations.
- A dual frequency (150-600 kHz) deep system for use aboard the U.S. Navy's research submarine NR-1.
- Several 600 kHz modular transducer sets rated to Full Ocean depth.

Sea Scan® PC is a registered trademark and U.S.Patents 5,142,502 and 5,142,503 cover all equipment.

SYSTEM DESCRIPTIONS

TOWED SYSTEMS

A complete Sea Scan® PC towed system consists of a personal computer, LCD flat panel display, keyboard, mouse, two specially designed towcables and a single frequency towfish. In addition, an operator's manual, small tool kit, asset of towcable line weights, five (5) hours of factory training and a one year limited warranty are part of the system. All components are shipped in rugged, foam lined, shipping containers. The system is covered by a one year limited warranty. A complete towed system with the shipping containers weighs, on average, 100 kg (220 lbs.).

The Sea Scan® PC towed system is available in three different configurations:

- A Desktop Sea Scan® PC system includes a rack mount case computer with Windows Me and an Intel™ based Pentium™ III processor or equivalent CPU. Additional features: 256 MB RAM, 60 GB hard drive, 3.5" floppy drive, internal R/RW CD drive, wireless mouse and keyboard, associated power cords and a 15" LCD flat panel monitor.
- A Portable Sea Scan® PC system includes a portable PC (SBS 904 or Fieldworks 8000) containing a CELERON/Intel™ Pentium™ processor with 32/64 MB RAM, a 30/6 GB hard

drive, 3.5"/CD Rom internal drive, mouse, keyboard, associated power cords and a color active display. Neither system is considered either "Splash-proof" or "Water-proof".

- The "CENTURION"◊ Splash Proof Sea Scan® PC system, designed and manufactured by MSTL, includes a small rugged case containing a 233 MHz CPU, 128 MB RAM, a 20 GB hard drive, increased connectivity and network/USB compatible. The system comes with a keyboard and waterproof mouse, an external GARMIN "eTrex" Legend GPS plus a second JRC D/GPS system and external R/RW CD-ROM drive. The "CENTURION"◊ features a 10.4" daylight readable screen for easier target recognition and detection. All external connections are splash proof. The unit has been designed for open boat operations in a rain and seawater spray environment. The system normal operates from a 12 VDC battery source. Computer dimensions are 13" x 11" x 6" and weight is 12 pounds.

Towfish

Each of the Sea Scan® PC systems contain one single frequency towfish available in the following frequencies: 150, 300, 600, 900, or 1200 kHz. The towfish is certified to an operating depth of 300-meters (984-ft.).

- The fish is constructed of solid polyvinyl chloride (PVC) and other non-corrosive materials.

TOWFISH SPECIFICATIONS

kHz	150	300	600	900	1200
Length (m/in)	1.1/42	1.1/42	1.1/42	1.1/42	1.1/42
Diameter (cm/in)	10.2/4	10.2/4	10.2/4	10.2/4	10.2/4
Weight in air (kg/lbs.)	16.8/37	15.9/35	15/33	15/33	15/33
Pulse Length (µsec/cycles)	33/5	20/6	10/6	6.7/6	5/6
Typical Range Resolution – (cm/in)	58/23(300)	29/11.4(150)	9.7/3.8(50)	7.8/3(40)	3.9/1.5(20)
Axial Resolution – aperture size (cm/in)	61/24	61/24	30.5/12	22.9/9	15.2/6
Typical Maximum Range (meters)	400-500	200-300	100	40	20

Towcables

- A 100 and 30-meter cable are standard with the towed system. Optional lengths are available up to 800 meters depending on the transducer frequency operating with the cable.
- The cable is constructed using three custom coaxial cables and a 545-kg (1250 lbs.) braided Kevlar ™ strength member covered by either a polyurethane or polyethylene outer jacket to a nominal cable diameter of approximately 0.36" or less.
- 100-meters of cable weighs 9.1 kg (20 lbs.) in air, 4.1 kg (9 lbs.) in water.
- The minimum safe bending radius is 13 cm (5 in.)

Towcable Line Weights

- A set of towcable line weights is a part of each towed system that enables the towfish to achieve greater operating depths. The weights are easily attached to the towcable through the use of two large electrical ties. The weights work best when placed on the cable 8 to 10 feet in front of the towfish

Maintenance

- The Sea Scan® PC system is virtually maintenance free. After use in saltwater the towfish, cable, and wet end connectors should be flushed with fresh water to reduce salt buildup. During cable/towfish hookup the wet end connectors should be sprayed with WD 40 to lubricate the "O" ring seal and clean out any water or dirt that may be in the connector. During cable and towfish storage, the dust shields should be installed to reduce dirt infusion and possible connector damage. Periodically the towcable should be checked for signs of wear and abrasion. A PC technician can perform computer repairs locally. Required repairs to either the Sea Scan® PC system or transducer electronics card must be performed at the factory. The towfish contains no serviceable parts that require either maintenance or adjustments in the field.

AUV/ROV SYSTEMS

MSTL's AUV/ROV systems have been designed and built to the exacting standards of today's AUV/ROV market. The AUV/ROV system components use the same proven technology found in the towed systems but have been redesigned to make them smaller and more energy efficient. A normal AUV/ROV system will consist of the system electronics card, transducer electronics card, a pair of transducers, and connecting cables. To satisfy the uniqueness of each AUV/ROV system, MSTL can tailor a system that ranges from just the basic side scan sonar components to a complete turn-key system that includes the PC, power supply, mounting brackets, connectors, cables, and pressurized containers.

System Electronics

- The Sea Scan® PC system electronics card (installed in the PC) is available in two configurations: Full size, full length, ISA card and a compact PC-104 card for embedded installations.

- System Electronics ISA Card: Size 340mm x 100mm x 19mm (13.4"x 3.9" x 0.75"), Weight: 361 gms (12.7 oz), Power consumption is 6-10 watts (Consumption is dependent on scanning speed and selected range scale).

- System Electronics PC-104 Card: Size 97mm x 92mm x 17mm (3.8" x 3.6" x 0.66"), Weight: 142 gms (5 oz), Power consumption is 4.8 watts maximum (Consumption can be lower depending on scanning speed and selected range).

Transducer Electronics Card

- The Sea Scan® PC transducer electronics card is available in the following frequencies: 150, 300, 600, 900 and 1200 kHz. The card can be mounted inside the AUV/ROV pressurized container or sealed as a wet version for mounting outside the vehicle. Dual frequency cards are available in any combination of frequencies desired by the customer. Standard depth rating, when the card is encased and mounted outside the AUV/ROV, is 300-meters. Greater depth ratings are available.

- Transducer Electronics Card: Size 188mm x 58mm x 23mm (7.4" x 2.3" x 0.9"), Weight 227 gms (8 oz) (unpotted card). Two cards are needed for a dual frequency system.

Transducer Modules

- Transducer modules are available in a variety of shapes, sizes and in the following frequencies: 150, 300, 600, 900 or 1200 kHz. MSTL can make custom shaped modules to meet specific applications. Standard modules are available with a 300-meter depth rating. Deep modules, with a depth rating of either 6000-meters or Full Ocean Depth, are available.

AUV/ROV TRANSDUCER SPECIFICATIONS

kHz	DF*	150	300	600	900	1200
Length (in/mm)	28/711	28/711	28/711	17.5/444	TBD	TBD
Width (in/mm)	4/102	3/76	2.25/57	1.5/38	TBD	TBD
Height (in/mm)	3/76	2/51	2/51	1.5/38	TBD	TBD
Weight (oz/gms)	16lbs/7.3kg	TBD	TBD	34.5/980	TBD	TBD

*Dual Frequency: 150/600 kHz, 300-meter depth rating.

SUBMERGED SYSTEM

MSTL manufactures a unique side scan sonar system for manned sonar operations from a wet underwater vehicle. Housed in a small pressure aluminum case, the unit is easily mounted inside with the transducers fix mounted to the hull. System features and specifications are listed below.

Features

- Sea Scan® PC hardware and software are housed in a pressure tested (tested to Mil Std) aluminum case.

- Windows™ ME operating environment.

- All components have successfully passed "Out Gassing" testing.

- Single or Dual Frequency configured, hull mounted transducers.

- Industrial 233 MHz Processor, 20 GB hard drive, external R/W CD ROM drive, 10.4" Color flat screen display.
- Navigation Data via Mil-1553 interface card or NEMA 0183 data stream.
- Keyboard for setup/file transfer.
- Unique underwater tilt mouse for system operations.

MagScan SYSTEM

This is the first commercially available combined side scan sonar and cesium magnetometer system; a new and powerful tool featuring simultaneous and extremely high resolution display of both data sets using a single towfish. This system provides real time confirmation of acoustic and magnetic effects for targets of all sizes in a user-friendly Windows™ interface.

Features

- High-resolution 600 or 900 kHz sonar images in conjunction with high quality marine magnetics. Sensitivity better than 0.002 nT at 1 Hz, 0.02 nT sensitivity at 10 Hz (samples per second).
- Single tow cable, 100-meter standard with an optional length 200-meter cable.
- Magnetometer cycle rates selectable from 100 Hz to 0.01 Hz.
- Sea Scan® PC side scan sonar specifications are the same as listed for the towed systems.

STANDARD Sea Scan® PC SYSTEM COMPONENTS

Operational Toolkit - Each system comes with a toolkit containing system applicable spare fuses, cable hardware, spanner wrench and other miscellaneous tools.

Operator's Training - Five (5) hours of factory training, for up to four individuals, is included in the price of each system. This training is designed to provide the basic information necessary to safely setup and operate the system. Areas covered in the classroom training include; fundamentals of sonar operations, operations and features of the system software, system setup and testing, side scan water operations, and system troubleshooting procedures. This training is conducted at the factory in White Marsh, Virginia. Travel and living expenses associated with this training are the responsibility of the customer.

Operation of the Sea Scan® PC system is easily learned by anyone who has a basic familiarity with computers and Windows™ operation. A training mode is also included in the operational software that provides the customer with the ability to practice all controls and functions, in the office or at home, prior to going to sea. Interpretation of the data collected is relatively easy since the image quality is near photographic. As operators gain experience with the system, minor details, shadows, etc. will become more apparent and meaningful.

Operator's Manual - A detailed operator's manual is shipped with each system. The manual provides information regarding sonar operations, system setup and testing, the Sea Scan® PC Software, and the Sea Scan® PC Review Program.

Shipping /Storage Cases - Rugged shipping/storage cases are provided with each system except the AUV/ROV systems, which are shipped in protective cartons. The cases contain foam inserts, which provide increased shock protection during handling and shipping.

Limited Warranty -All equipment provided by Marine Sonic Technology, Ltd. is warranted to be free from defects in materials or workmanship for a period of (1) one-year from the date of the original purchase. This warranty covers the original purchaser and is not transferable. The warranty does not cover damage or loss due to abuse or improper handling/operations. Warranty repairs are normally performed at the factory but in some instances local area representatives may make repairs. The cost to return equipment for warranty repairs is the responsibility of the customer.

OPTIONAL EQUIPMENT

Extended Limited Warranty – MSTL is now offering an Extended Limited Warranty Plan that can extend the warranty period up to THREE YEARS from the date of purchase. This is a very cost-effective way of adding increased system protection.

Maintenance and Service Plan – This plan provides yearly preventive maintenance checks/services and warranty repairs when required. Depending on the plan selected maintenance and warranty coverage can be extended out to FOUR YEARS. This plan insures that the system is operating at peak performance at all times.

On-Site Training – On-site training packages, that include both classroom and on-water training, are available and can be tailored to meet specific customer needs. With on-site training, classroom and training boat are the responsibility of the customer.

On-Water Training - MSTL offers an on-water training option that provides the customer with hands-on experience operating the system under the supervision of MSTL personnel. The training is conducted in local Virginia waters aboard MSTL's 36-foot "Sonic Boom". Training includes system setup and testing, discussion of various tow point options, proper boat towing procedures, winch operations, regulating towfish depths, emergency towfish recovery, and side scan search procedures.

GPS – The "Centurion" Splash Proof system comes standard with two GPS systems. The first is a small waterproof Garmin "eTrex" Legend GPS system, which provides an accuracy of approximately 15 meters. The Legend is also WASS capable and if a WASS signal is received accuracy is less than 3 meters. The second is a JRC D/GPS system, which will provide accuracy in the 3-5 meter range. The accuracy listed is dependent on weather conditions and satellite reception.

Stand Alone GPS/DGPS Receivers – Several different GPS or DGPS options are available as stand alone systems for the Portable and Desk Top systems. These units can input navigational information to the Sea Scan® PC, autopilots, digital charts, plotters, and other marine instruments.

Splash Proof Battery Box – The Splash Proof System can be ordered with a self-contained battery box that provides a 12 VDC power source for 8 hrs of scanning operations. The battery box contains a charger and four 12 VDC closed cell batteries.

Removable Media Discs – Desktop models include a built in a R/RW CD drive capable of storing up to 650 MB and a 3.5" internal drive. With the R/RW CD drive the customer can quickly transfer large quantities of image data to other computers for analysis or archive purposes. Since the Sea Scan® PC system operates in a PC, virtually any mass storage device available will interface with the system.

Additional Towfish – One single frequency towfish comes standard with each towed system. Additional frequency towfish should be considered to maximize the capabilities of the system and to provide a backup in case of loss or damage to the primary towfish. A combination that works well together is to have a long-range towfish (150 – 300 kHz) and a high-resolution shorter-range towfish (600, 900 or 1200 kHz). It takes only a few minutes to retrieve and change to a different towfish.

Spare Towcables – Two cables (100-meter and 30-meter) come standard with each towed system. When scanning depths are greater than 50-meters, a cable length longer than 100-meters is needed. Cable lengths up to 800-meters are available, depending on the transducer frequency being used.

12 VDC to 115 VAC Inverters – Several of the Sea Scan® PC systems require 115 or 230 VAC power from either an onboard generator or a DC to AC inverter. High quality inverters are available, which are fully tested for noise free operation.

Analog Output – In certain situations a real time hard copy printout of the images is desired. MSTL offers an analog output capability for operation with a paper recorder on our Desk Top and Portable systems. This option is not available with the Centurion ™.

SEA SCAN® PC SYSTEM FEATURES:

All sonar functions, regardless of the Sea Scan® PC system, are software controlled. The features listed below apply to all systems manufactured by MSTL.

Controls:

- **Power** – Selectable on/off
- **Acoustic Range Scales** - 5, 10, 20, 50, 75, 100, 150, 200, 300, 500 meters (Range listed is out from each side of the transducer. Multiply x 2 to determine total swath scanned). Additional ranges of 30 and 40-meters are available where the PC 104 card is installed.
- **Magnetometer Range Scales** (Only applicable to MagScan System) -1/10, 1/20, 1/50, 10/50, 10/100, 20/100, 50/500, 100/500, gamma per division.
- **Display Color Scales** - Gray, Brown, Bronze, Gold, Mixed, HSV, Hot, Pink, Cool, Bone, Jet, Copper, and Custom. All color scales can be viewed inverted.
- **Time Gain Compensation** (TGC) – Automatic or manual.
- **Speed Control** – Automatically controlled with GPS/DGPS input or manual input.

- **Zoom** – Click and drag zoom window or centered. Both support multiple zooms.
- **Length Measurement** – Distances measured on images in feet, yards, or meters.
- **Area Measurement** – Areas measured in square feet, yards, or meters.
- **Height Measurement** – Shadows created by objects, displayed in the images, can be triangulated to determine height above the sea floor.
- **Channel Selection** – Displays either left or right channels or both left and right channels.
- **Annotations** – Notes regarding details of observed images can be added to images in real time or during post processing analysis.
- **Markers** – Objects in the acoustic image or anomalies in the magnetometer strip chart can be marked in the plotter, which stores the target location, target height, water depth and the magnetic field of information for post analysis. All data is stored in a text file
- **Event Markers** – Event markers can be input by an external source via the serial port or automatically by the system software using selectable ranges.
- **Range Delay** – Range scales can be delayed to eliminate the water column or offset range for optimum viewing/collection.
- **Navigation Plotter** – The integrated full-featured navigation plotter correlates all acoustic information to geographic positions. Up to 100 navigation waypoints can be entered into the plotter. Objects in the acoustic image can be quickly transferred to the plotter. Plotter information can be displayed simultaneously and overlaid on the sonar image in real time.
- **Filter** – More than 50 mathematical filters are available to enhance the acoustic images. These filters are located in the Sea Scan® PC Review Program.

Inputs

- **Desktop Systems** – Operate on either 115 or 230 VAC.
- **Portable and MagScan® Systems** – Operate on either 115/230 AC and/or 12 VDC. Operating voltage depends on the model selected.
- **"Centurion" Splash Proof-** Operates on 12 VDC.
- **AUV and Submerged Systems** – Operate on voltages from 10 to 36 VDC (5.5 amps at 12 VDC, 2.5 amps at 24 VDC)
- **Navigation Input** – Accepts a NEMA 0183 stream from the GPS/DGPS.
- **Analog Inputs** – The towfish provides analog image data that is converted, displayed and stored as digital data.
- **Host/Remote Control** – This feature allows the system, installed in an AUV/ROV, to be controlled from a remote computer using a standard serial port communication.
- **Fathometer** – Water depth data can be input into the system from a Fathometer outputting a NEMA 0183 depth information string. This information can be inputted into the computer from the Fathometer through a standard serial port communication. The depth data can be displayed onscreen overlaid on the image.
- **Event Markers** – Either the operating system or an external source using the standard serial port communication can enter event markers.

Outputs

- **Acoustic Data** – All acoustic data is stored digitally in a MST file format.
- **TIFF Files** – Images can be converted to the standard TIFF file format from the Sea Scan® PC Review Program for use in publishing programs.
- **Navigation Data** – All navigation information is stored digitally in the SVY (Survey) file format (text file).

- **Fathometer Data** – All Fathometer data is stored digitally in the DPT (Depth) file format (text file).
- **Marker** – All marker information is stored digitally in the MKR format (text file).
- **Magnetometer Data** – All magnetometer data is stored digitally in the MAG file format (text file).
- **Printer** – Images can be printed from any PC compatible printer.
- **Analog Output** – As an option, analog output can be provided so that real time, hard copy images can be printed during scanning operations.

Revised September 9, 2002

odom

Echotrac this latest generation of the echotrac dual frequency survey echo sounder brings into use the best of available technologies in high-resolution thermal printing, microprocessor and dsp techniques, and flat screen graphic displays. the sonar transceiver, echo processor, graphical operator interface and hard copy recorder are all housed in one portable, splash-proof case. the unit is suited to table top, bulkhead or rack mounting and is equally at home on either small survey launches or large ships. well suited for use in the shallows of rivers and harbors, the mission variable unit is also capable of working to depths of over 2,000 meters.

FEATURES

Frequencies: Either single or dual frequency configurations of the unit are available: Standard frequencies are 200 and 24kHz or 210 and 33kHz.

Optional frequencies
High: 100kHz to 1MHz
Low: 10kHz to 60kHz
Side Scan: Single channel 200kHz

Printer: The high-resolution, thin-film thermal printhead measures 216mm (8.5") wide. Resolution is 8 dots/mm (203/in.) along the print axis and 8 lines/mm along the paper axis. The unit is capable of printing up to 16 gray shades, the number of shades being selectable by the operator.

Display: The graphical LCD module (320 x 200 pixels) measures 156.4mm (6" diagonally). Fluorescent Back Lighting (CFL) of the paper-white display provides excellent visibility in all light conditions. In dual frequency operation, both high and low frequency depth values are displayed continuously.

Keypad: A 16-key NEMA, 12 sealed unit with tactile feedback is used by the operator for parameter selection and numerical value entry. Ten digits, Up, Down, Left and Right arrow keys, Decimal Point/HELP and Enter keys are provided.

Digitizer: The bottom tracking capabilities of the unit are enhanced by utilizing the DSP capabilities of the digitizer processor. These DSP algorithms yield reliable bottom detection even in the presence of high ambient noise and multiple returns.

COMMUNICATIONS

Interfacing & Annotation: Four bi-directional RS-232 serial ports are standard. Depth information is output after each sounding cycle with the standard string, including values for both the high and low channels in dual-frequency operation. Output strings conforming to NMEA and other major echo sounder formats are available. In addition, system parameters can be configured via Comm 1. The Echotrac accepts annotation of up to 80 characters (printed on the Fix Mark Line). Standard NMEA formats from GPS receivers, as well as proprietary strings from positioning and navigation systems, can also be annotated on the chart. Interfacing to data acquisition systems is asynchronous and does not require handshaking.

Heave Compensation: Interfacing to most available motion sensors is provided over a dedicated RS-232 serial port. In addition to the "raw seabed," both Heave data (scaled values from the motion sensor) and a "corrected seabed" (Heave data applied to the digital depth) are printed on the chart in real-time.

CONTROLS

Analog Controls: Immediate access to critical analog controls is via front panel mounted potentiometers and switches. They include: Receive Sensitivity, AGC (Automatic Gain Control) Transmit Power and Threshold (digitizer level). Also mounted on the front panel are controls for the printer including: Chart ON/OFF, Paper Advance, Paper Take-up and Mark.

Digital Parameters: Listed below are some of the functions of the MKII, which are controlled using the display (through its system of pull-down menus) and the keypad.

Frequency: High, Low or Dual

Chart Scale (phasing): Manual or Auto Bottom-tracking

Chart Center: Determines where the center of the chart is placed (at what depth) in Manual Scale.

Chart Width: Sets the width of the chart from 15 meters (60 ft.) minimum to 150 meters (360 ft.) maximum.

Chart Speed: Sync-for every sounding the printer advances the chart one dot row (varies with depth). In fixed speeds—from 1cm/min (1") to 20cm/min (8").

Print Parameters: Prints the values of all digital parameters on the chart.

Plot Signal: Plots a line on the chart scaled to the relative amplitude of each return pulse.

Annotation: Prints Fix Number, Time, Depth and Position on the chart.

Zoom: Changes the printer resolution so that the return is printed in 1/2 of the minimum scale width (7.5m or 30 ft.).

Units: Meters (cm. Resolution to 599.99m) Feet, or Fathoms

Cal Depth: Forces the digitizer to lock to the calibration target and ignore the bottom.

Velocity: Variable from 1,370 to 1,700 m/sec. (4,500 to 5,600 ft./sec)

Draft: Can be set from 0 to 40m (0-50 ft.) independently in both High and Low frequencies.

Blanking: Masks the digitizer from seeing returns shallower than the selected value. The value can be set from 0 to 5,920m.

Slope: Controls the response rate of the digitizer (tracking gate).

Ping Rate: Selectable from 1 to 20 "Pings"/sec. or automatic (based on end of scale value)

Pulse Width: The length of the transmit pulse is selectable based on the frequency installed. The number of cycles per "Ping" can be varied from a minimum of 2 to a maximum of 128.

Minimum Depth Alarm: 0-200m (0-700 ft.) Alerts the operator that the vessel has passed a depth shallower than the minimum selected.

Noise Filter: On – Off, the integrating filter eliminates high frequency noise in the return signal.

Gauge: Tide Gauge or River Stage correction.

HELP

A description of each parameter and its minimum and maximum value is available to the operator by pressing the HELP key.

DIAGNOSTICS

Communication to and from the MKII can be checked by turning the LCD display into a virtual computer terminal. This feature provides a positive check of all serial ports.

UNIT DIMENSIONS

Height: 470mm (18.5")
Width: 432mm (17")
Depth: 279mm (11")

WEIGHT

21.7kg (48 lb.)

POWER REQUIREMENTS

11-28 VDC, 110/220 VAC (50/60 Hz.) < 100 watts average power. Specify AC or DC at time of order.

OPERATING TEMPERATURE

0° to 55° C in conditions of humidity up to 95% non-condensing.

odom
HYDROGRAPHIC SYSTEMS

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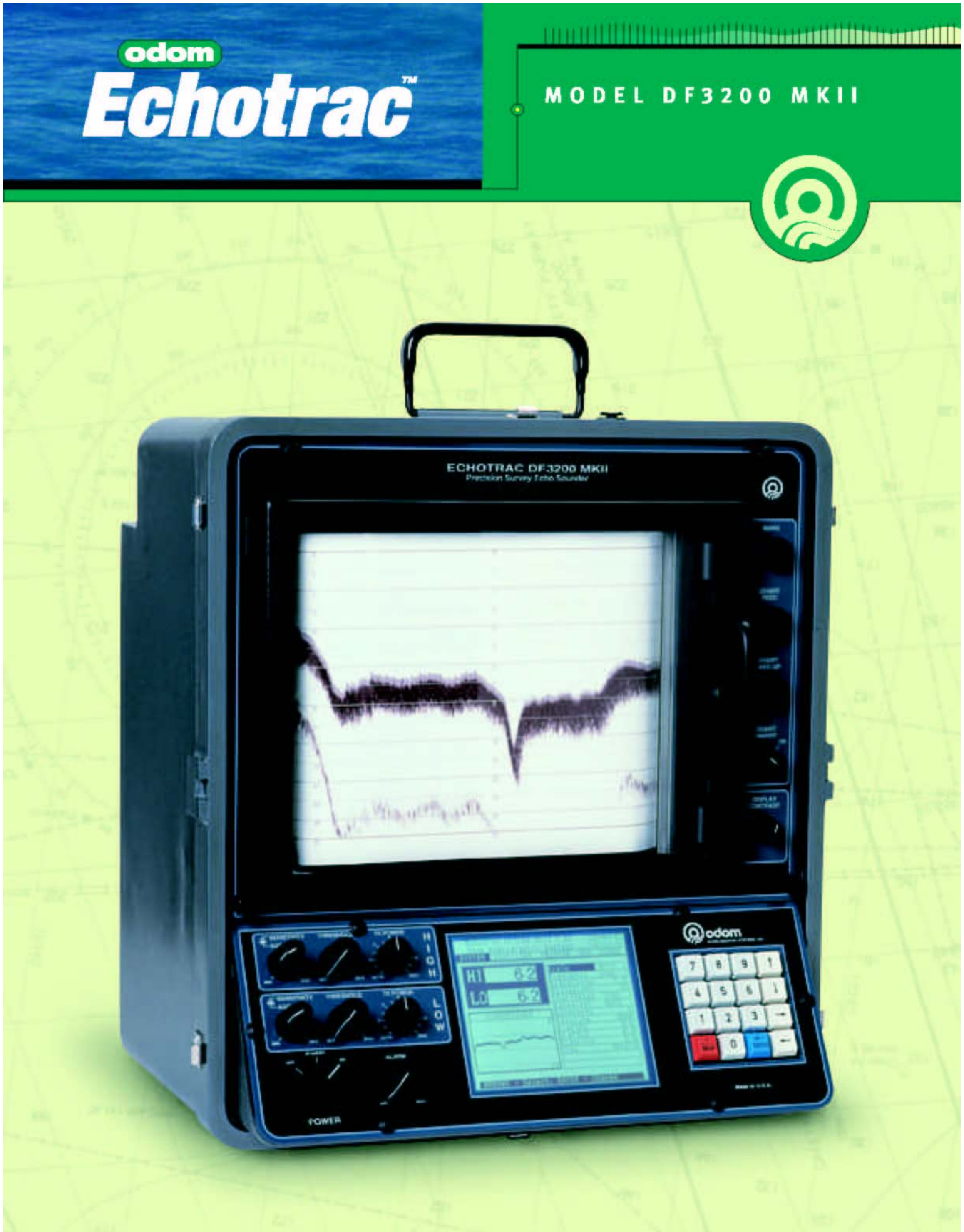
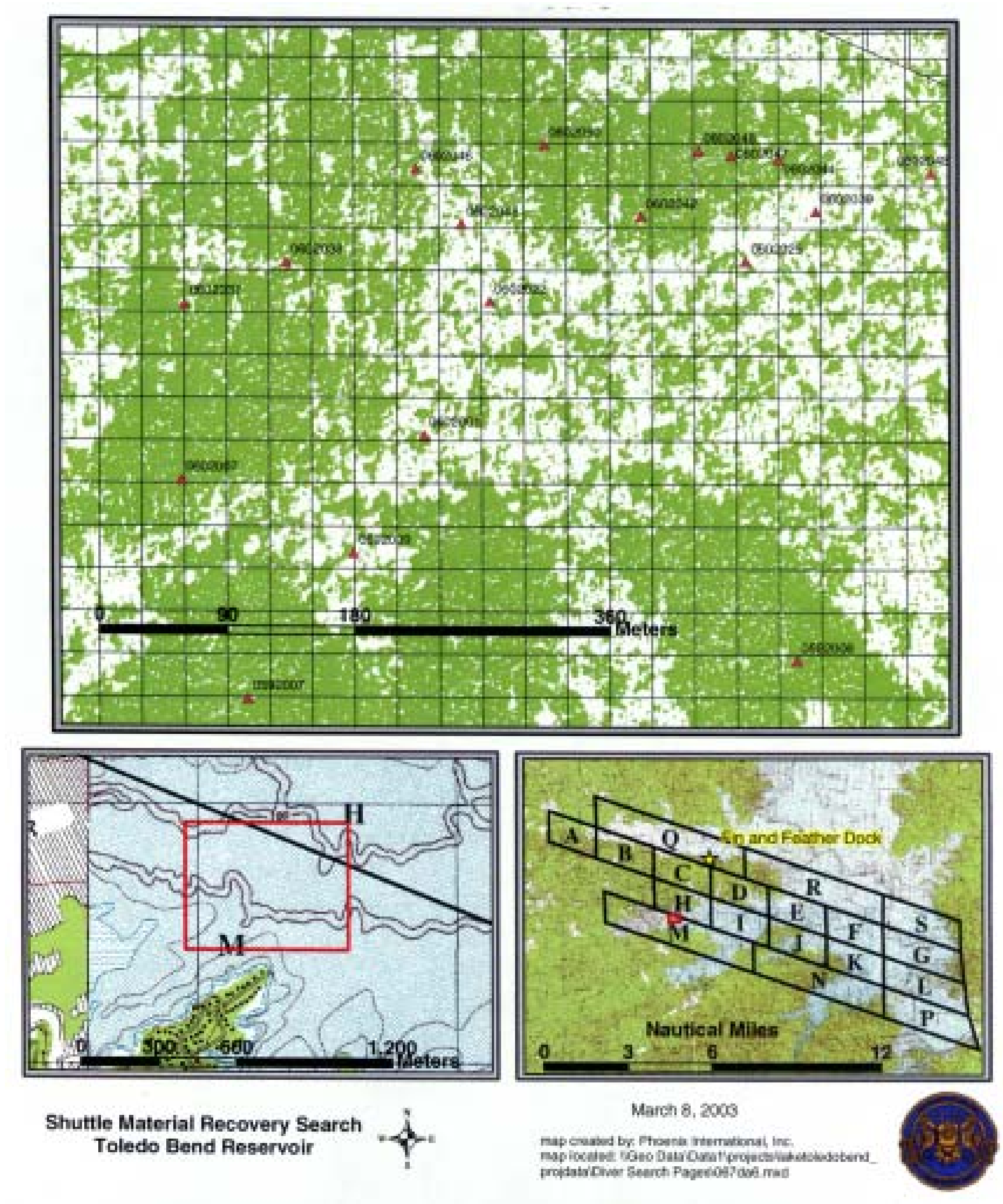

odom
Echotrac™
MODEL DF3200 MKII
ECHOTRAC DF3200 MKII
POWER

SAMPLE DIVE TEAM

ASSIGNMENT PACKAGE

Dive Area 6


0
90
180
360
Meters
H
M
0
300
600
1,200
Meters
A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
Q
R
S
Fin and Feather Dock
Nautical Miles
0
3
6
12
Shuttle Material Recovery Search
Toledo Bend Reservoir
March 8, 2003

Target Identification Dive Area

Target ID	Target Longitude	Target Latitude	Grid Center Longitude	Grid Center Latitude
Target Description				
0592006	W93 44.435	N31 14.524	W93 44.43289	N31 14.5181
Target Description: .82m irregular object casting a shadow, possibly a log				
0592007	W93 44.679	N31 14.508	W93 44.67848	N31 14.5004
Target Description: .57x.35m rectangular object				
0592009	W93 44.632	N31 14.564	W93 44.64119	N31 14.5656
Target Description: 1m 'donut-shaped' object casting shadow, possibly fish or a large stump				
0602001	N93 44.601	N31 14.609	W93 44.60377	N31 14.6145
Target Description: small faint tgt w/shdw .41m x .56m H				
0602007	N93 44.709	N31 14.591	W93 44.71705	N31 14.5976
Target Description: .75 L x .4m H Small tgt w/shdw in shallows				
0602022	W93 44.572	N31 14.660	W93 44.56634	N31 14.6635
Target Description: 1.0m L x .6m W x .68m H Irregular tgt w/shdw				
0602025	W93 44.458	N31 14.676	W93 44.45306	N31 14.6804
Target Description: 1.48m L x .57m W x .38m H irregular tgt w/shdw				
0602037	W93 44.708	N31 14.658	W93 44.69866	N31 14.6627
Target Description: .49m X .45m H small straight tgt w/shdw in dense trees				
0602038	W93 44.663	N31 14.674	W93 44.66098	N31 14.6791
Target Description: 1.0m x 1.5m irregular shaped tgt no shadow				

Target Identification Dive Area

Target ID	Target Longitude	Target Latitude	Grid Center Longitude	Grid Center Latitude
Target Description				
0602039	W93 44.427	N31 14.695	W93 44.43429	N31 14.6967
Target Description: .55m x .28m H circular tgt w/shdw on clean bottom				
0602042	W93 44.505	N31 14.693	W93 44.50989	N31 14.6963
Target Description: .9m small thin tgt on clean bottom w/slight shdw				
0602043	W93 44.376	N31 14.710	W93 44.37771	N31 14.7133
Target Description: .21m x .51m tgt no shdw w/line leading of the record				
0602044	W93 44.444	N31 14.715	W93 44.45331	N31 14.7128
Target Description: .45m x .35m H small oblong tgt w/shdw on clean bottom				
0602045	W93 44.585	N31 14.689	W93 44.58550	N31 14.6958
Target Description: 2.5m x 2.27m irregular tringular tgt w/shdw				
0602046	W93 44.605	N31 14.710	W93 44.60453	N31 14.7120
Target Description: .5m x .5m intenst tgt no shdw on clean bottom				
0602047	W93 44.465	N31 14.716	W93 44.47222	N31 14.7127
Target Description: .41m x .52m H small faint tgt w/shdw on clean bottom				
0602048	W93 44.479	N31 14.718	W93 44.47222	N31 14.7127
Target Description: .7m x .22m intense tgt on clean bottom w/slight shdw				
0602050	W93 44.548	N31 14.720	W93 44.54782	N31 14.7123
Target Description: .55m Dia circular tgt x .22m H w/shdw on fairly clean bottom				

Daily Team Target Assignment and Roster

Saturday, March 08, 2003

Dive Area: 6

Dive Team: ______________________

Targets Assigned:	Results:	Cleared - C Not Cleared - N Shuttle - S
0602039		
0592007		
0592009		
0602001		
0602007		
0602022		
0602025		
0592006		
0602038		
0602050		
0602042		
0602043		
0602044		
0602045		
0602046		
0602047		
0602048		
0602037		

Target Identification Dive Area

Target ID
0592006

Lon DD MM,mm	***Lat DD MM,mm***	***Depth***
W93 44.435	N31 14.524	

SECTOR	***Centroid LON***
M	W93 44.43289
GRID	***Centroid LAT***
M12517	N31 14.5181

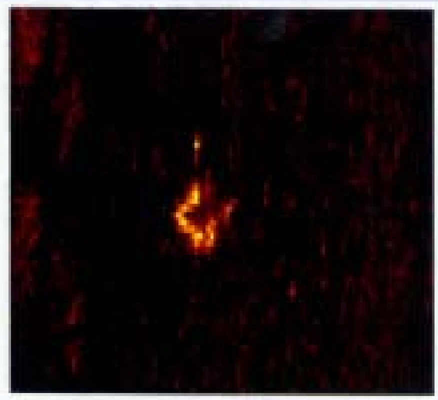
Description
.82m irregular object casting a shadow, possibly a log

Target ID
0592007

Lon DD MM,mm	***Lat DD MM,mm***	***Depth***
W93 44.679	N31 14.508	

SECTOR	***Centroid LON***
M	W93 44.67848
GRID	***Centroid LAT***
M12359	N31 14.5004

Description
.57x.35m rectangular object

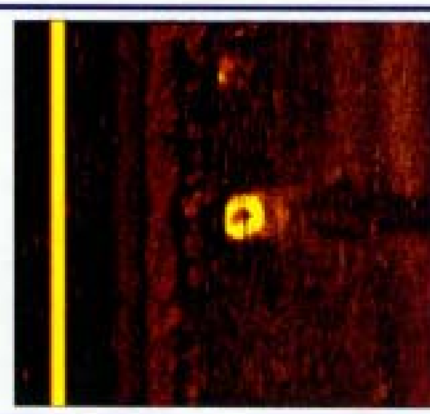


Target ID
0592009

Lon DD MM,mm	***Lat DD MM,mm***	***Depth***
W93 44.632	N31 14.564	

SECTOR	***Centroid LON***
M	W93 44.64119
GRID	***Centroid LAT***
M12916	N31 14.5656

Description
1m 'donut-shaped' object casting shadow, possibly fish or



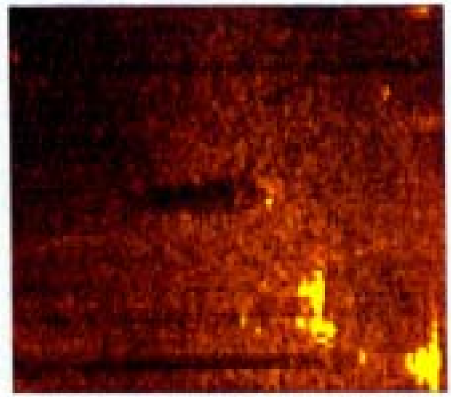
Target Identification Dive Area

Target ID
0602001

Lon DD MM,mm	Lat DD MM,mm	Depth
N93 44.601	N31 14.609	

SECTOR	Centroid LON
M	W93 44.60377
GRID	**Centroid LAT**
M13282	N31 14.6145

Description
small faint tgt w/shdw .41m x .56m H

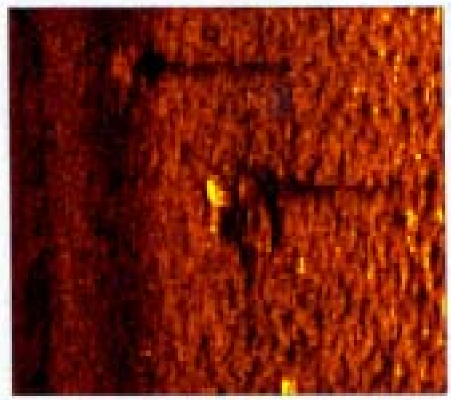


Target ID
0602007

Lon DD MM,mm	Lat DD MM,mm	Depth
N93 44.709	N31 14.591	

SECTOR	Centroid LON
M	W93 44.71705
GRID	**Centroid LAT**
M13164	N31 14.5976

Description
.75 L x .4m H Small tgt w/shdw in shallows

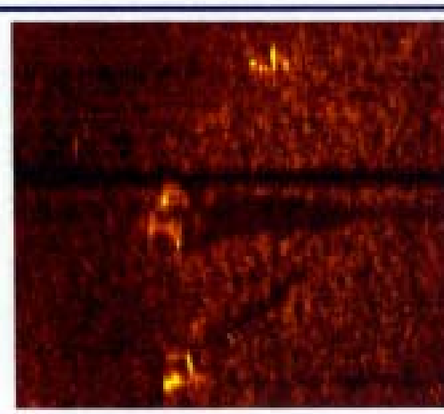


Target ID
0602022

Lon DD MM,mm	Lat DD MM,mm	Depth
W93 44.572	N31 14.660	

SECTOR	Centroid LON
M	W93 44.56634
GRID	**Centroid LAT**
M13572	N31 14.6635

Description
1.0m L x .6m W x .68m H Irregular tgt w/shdw



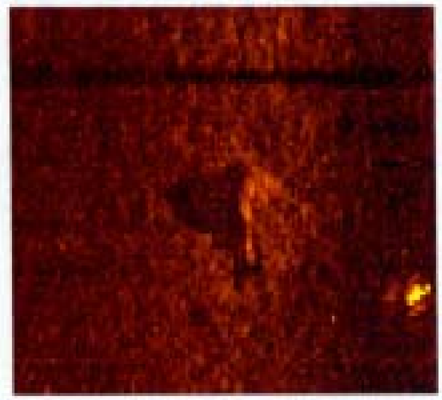
Target Identification Dive Area

Target ID
0602025

Lon DD MM,mm	*Lat DD MM,mm*	*Depth*
W93 44.458	N31 14.676	

SECTOR	***Centroid LON***
M	W93 44.45306
GRID	***Centroid LAT***
M13661	N31 14.6804

Description
1.48m L x .57m W x .38m H irregular tgt w/shdw

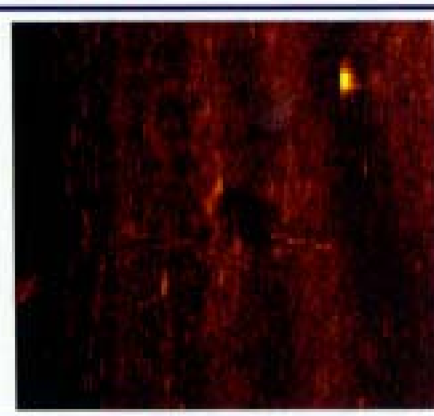


Target ID
0602037

Lon DD MM,mm	*Lat DD MM,mm*	*Depth*
W93 44.708	N31 14.658	

SECTOR	***Centroid LON***
M	W93 44.69866
GRID	***Centroid LAT***
M13565	N31 14.6627

Description
.49m X .45m H small straight tgt w/shdw in dense trees

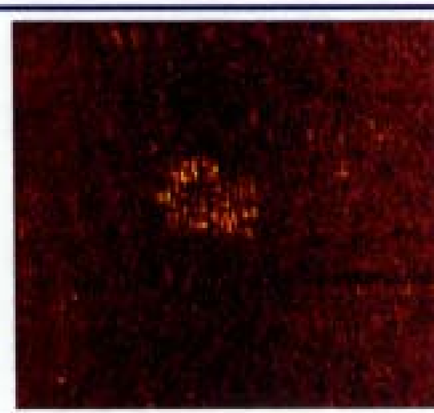


Target ID
0602038

Lon DD MM,mm	*Lat DD MM,mm*	*Depth*
W93 44.663	N31 14.674	

SECTOR	***Centroid LON***
M	W93 44.66098
GRID	***Centroid LAT***
M13650	N31 14.6791

Description
1.0m x 1.5m irregular shaped tgt no shadow



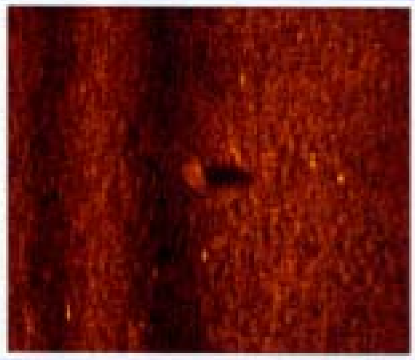
Target Identification Dive Area

Target ID
0602044

Lon DD MM,mm	Lat DD MM,mm	Depth
W93 44.444	N31 14.715	

SECTOR	Centroid LON
M	W93 44.45331
GRID	**Centroid LAT**
M13828	N31 14.7128

Description
.45m x .35m H small oblong tgt w/shdw on clean bottom



Target ID
0602045

Lon DD MM,mm	Lat DD MM,mm	Depth
W93 44.585	N31 14.689	

SECTOR	Centroid LON
M	W93 44.58550
GRID	**Centroid LAT**
M13736	N31 14.6958

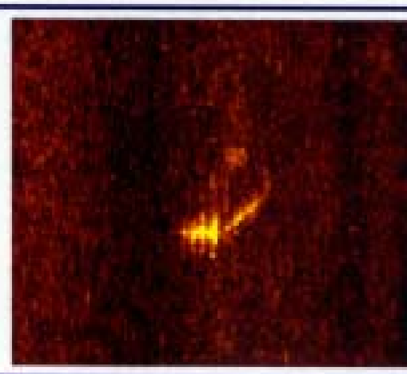
Description
2.5m x 2.27m irregular tringular tgt w/shdw

Target ID
0602046

Lon DD MM,mm	Lat DD MM,mm	Depth
W93 44.605	N31 14.710	

SECTOR	Centroid LON
M	W93 44.60453
GRID	**Centroid LAT**
M13820	N31 14.7120

Description
.5m x .5m intenst tgt no shdw on clean bottom



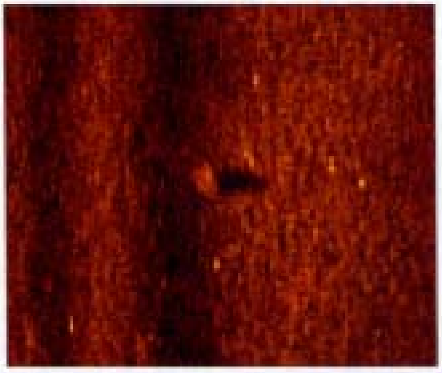
Target Identification Dive Area

Target ID
0602044

Lon DD MM,mm	*Lat DD MM,mm*	*Depth*
W93 44.444	N31 14.715	

SECTOR	**Centroid LON**
M	W93 44.45331
GRID	**Centroid LAT**
M13828	N31 14.7128

Description
.45m x .35m H small oblong tgt w/shdw on clean bottom

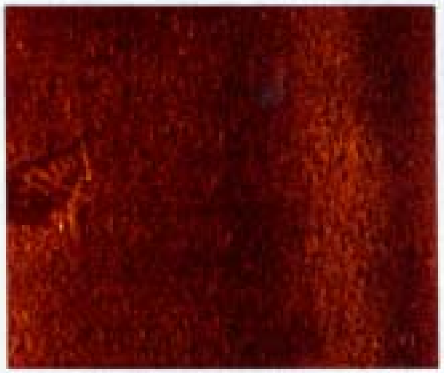


Target ID
0602045

Lon DD MM,mm	*Lat DD MM,mm*	*Depth*
W93 44.585	N31 14.689	

SECTOR	**Centroid LON**
M	W93 44.58550
GRID	**Centroid LAT**
M13736	N31 14.6958

Description
2.5m x 2.27m irregular tringular tgt w/shdw

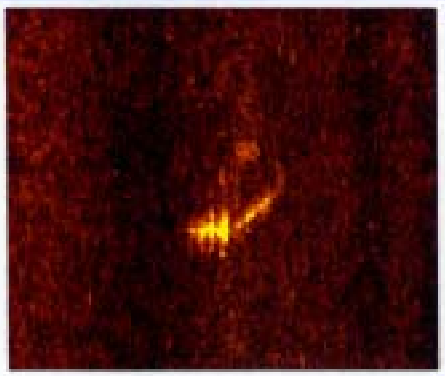


Target ID
0602046

Lon DD MM,mm	*Lat DD MM,mm*	*Depth*
W93 44.605	N31 14.710	

SECTOR	**Centroid LON**
M	W93 44.60453
GRID	**Centroid LAT**
M13820	N31 14.7120

Description
.5m x .5m interist tgt no shdw on clean bottom



Target Identification Dive Area

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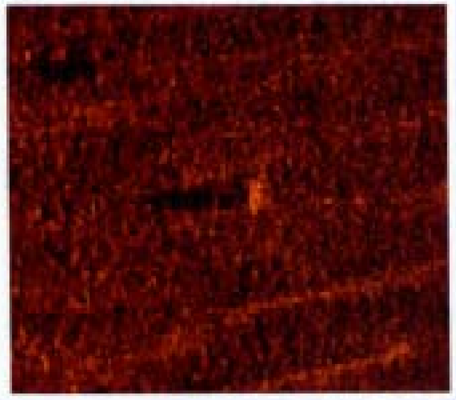
Target ID
0602047

Lon DD MM,mm	Lat DD MM,mm	Depth
W93 44.465	N31 14.716	

SECTOR	Centroid LON
M	W93 44.47222
GRID	**Centroid LAT**
M13827	N31 14.7127

Description
.41m x .52m H small faint tgt w/shdw on clean bottom

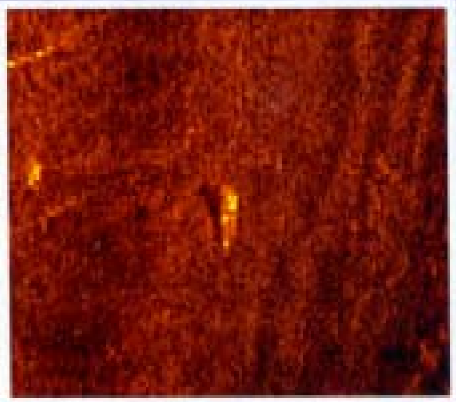


Target ID
0602048

Lon DD MM,mm	Lat DD MM,mm	Depth
W93 44.479	N31 14.718	

SECTOR	Centroid LON
M	W93 44.47222
GRID	**Centroid LAT**
M13827	N31 14.7127

Description
.7m x .22m intense tgt on clean bottom w/slight shdw



Target ID
0602050

Lon DD MM,mm	Lat DD MM,mm	Depth
W93 44.548	N31 14.720	

SECTOR	Centroid LON
M	W93 44.54782
GRID	**Centroid LAT**
M13823	N31 14.7123

Description
.55m Dia circular tgt x .22m H w/shdw on fairly clean botto