Ascension Island Hydroacoustic Data System

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Hugh Thomson
(Naval Facilities Engineering Service Center, Port Hueneme, CA)

Dallas Meggitt
(Sound & Sea Technology, Edmonds WA)

Edward Saade
(Thales Geosolutions (Pacific), Inc. San Diego CA)

Abstract

Over 50 nuclear explosions were registered between 16 July 1945, when the first nuclear explosive test was conducted by the United States at Alamogordo, New Mexico, and 31 December 1953. Increasing concern about the effects of nuclear tests led to a series of international treaties limiting nuclear tests, culminating in the Comprehensive Nuclear Test-Ban Treaty in 1996. The CTBT, which prohibits all nuclear test explosions in all environments, was opened for signature in New York on 24 September 1996, when it was signed by 71 States, including the (then) five nuclear-weapon States. A critical element of the treaty is the capability to verify compliance with the Treaty.

The United States and other signatories have responsibilities under the Treaty to provide various means for monitoring compliance with the Treaty. The United States Air Force Technical Applications Center (AFTAC) is tasked with monitoring compliance of nuclear test ban treaties for the US and the CTBT Organization in Vienna, Austria. AFTAC utilizes several different techniques, each designed to monitor a specific physical domain (i.e. underground, space, oceans, etc.). Together, these monitoring systems, equipment, and methods form the US Atomic Energy Detection System (USAEDS).

An essential part of the USAEDS is the Hydroacoustic Data Acquisition System (HDAS). The HDAS consists of underwater sensor systems linked to shore facilities with undersea data transmission cables, and shore based computers for data storage and transmission to the National Data Center (NDC). HDAS sensors are installed at Diego Garcia (Indian Ocean), Cape Leeuwen, Australia and Juan Fernandez Island, (South Pacific Ocean). Another HDAS system is to be installed at Ascension Island (AI), a volcanic island located in the South Atlantic Ocean, with one array located north and one array south of the island, with cabling back to shore at Southwest Bay. Figure 1 shows the location of Ascension Island.

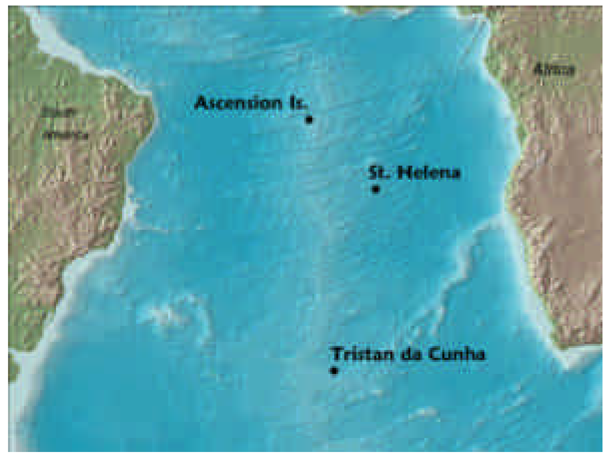

Figure 1
Ascension Island

In preparation for installation of the HDAS cable and sensors at Ascension Island, a detailed Desktop Study, Marine Cable Route and Sensor Site survey and shore landing preparations were needed. The extremely remote location of the island and the volcanic nature of the island required unique approaches for the survey and shore landing operations. This paper describes the background of the HDAS installation and previous surveys at Ascension Island and provides an overview of completed and planned operations.

1. INTRODUCTION

The HDAS installation at Ascension Island is to comprise two hydrophone sensor systems connected to the island by two undersea cables landed at Southwest Bay, as shown in Figure 2.

Figure 2
Ascension Island HDAS Installation

Undersea cables for previous monitoring systems at Ascension Island have failed over the years due to the high energy wave environment at the beach where they were brought ashore. A continual problem has been the survivability of cables in the near shore area of the site. Large waves enter Southwest Bay and break within a few feet of the shore, as shown in Figure 3.

Figure 3
Southwest Bay Surf

This eventually damages the split pipe cable protection (Figure 4), resulting in failure of the cables. The previous cables were across the sandy beach and trenched into the sand. Although they were installed with split pipe and secured in place on the seafloor, the high-energy surf and short breaking wave action resulted in numerous cable failures and frequent repairs.

Figure 4
Split Pipe Failure at Southwest Bay, Ascension Island

Because of the history of failures of split-pipe protected cables at the Southwest Bay landing site, NFESC conducted a life-cycle cost analysis of alternative methods of landing and protecting the Ascension Island cables. Based on the results of the analysis, NFESC recommended to AFTAC that the use of directionally drilled bores be investigated for landing the cables for the new HDAS system at Ascension Island.

Directionally drilled bores (DDBs), also commonly referred to as horizontal drilling, are an increasingly frequent means for landing and protecting undersea cables, particularly at sites that experience high-energy wave or current conditions offshore. This technique drills a subsurface hole from the shore out to sea to a water depth beyond the wave and surf action. A conduit for the cable is left in the hole or pulled into it. This technique eliminates the wave-induced hazards to the cable, provided the bore exits to the seafloor in a relatively benign area that will have minimal effects from wave or storm activity. The exit location (and water depth) is highly site dependent. Establishing an appropriate exit location requires a detailed survey of the seafloor, including bathymetry, imagery and seafloor sediment and subbottom properties.

In addition, the directional drilling approach often is substantially less intrusive to the environment. This was an important consideration at Ascension Island. The beach at Southwest Bay is a major nesting and hatching area for the Atlantic green sea turtle, an endangered species. The beach is also a nesting area for the Sooty Tern, another species of concern. Landing the cables using a trench up the beach would have limited operations to times when turtles or their eggs, or birds were not present, significantly limiting the window for landing the cables. DDBs also can separate in time the shore landing activities from the cable laying operations. This substantially reduces the risk of weather or equipment problems on either operation affecting the other one.

The logistics of large-scale operations at Ascension Island are challenging. There are weekly flights to and from the island, but only one flight a month is a cargo flight (usually a C-17) capable of moving large equipment. Bulky or extremely heavy equipment is transported to the island by a ship that makes the trip once every two months. The facilities and supplies on the island are limited, necessitating that a project of the magnitude of the DDB installation be effectively self-contained and self-supporting. The successful installation of the HDAS DDBs required the close cooperation of numerous Air Force, Navy and contractor organizations in planning and carrying out the operation.

2. ASCENSION ISLAND HDAS PROJECT ACTIVITIES

The shore landing activities for the Ascension Island HDAS cables included:

- a detailed desktop survey that compiled and analyzed the all of the available on the waters along the planned cable routes
- a comprehensive bathymetric and imagery survey using multibeam echosounder technology
- installation of three directionally drilled bores for landing the HDAS shore cables.

Each of these activities is described in detail in separate papers [1], [2], [3]. [4]. This paper summarizes the project activities and the results of the project to date.

3. ANALYSIS OF AVAILABLE DATA

A comprehensive desktop study [5] was compiled that evaluated all of the available data that could be found on the waters and seafloor off Ascension Island and the planned landing site at Southwest Bay. The purpose of this study was to examine possible cable routes for the installation of two Hydroacoustic Data Acquisition System (HDAS) arrays at Ascension Island as part of the United States Atomic Energy Detection System, in support of the Comprehensive Test Ban Treaty.

Ascension Island lies near the equator in the South Atlantic Ocean, approximately half way between Africa and South America, about 80 km west of the Mid-Atlantic Ridge. The island is roughly triangular in shape, 10 X 14 km, and its tallest peak is 879 m above sea level. The island rises some 3200 meters from the seabed. Two HDAS locations were proposed, one on a ridge about 25 km northwest of the island and a second on a seamount about 120 km south-southwest of the island. The Royal Air Force and the United States Air Force maintain support facilities, including an airfield, on Ascension Island. Cables for the Missile Impact Locating System (MILS) that is no longer in use were landed at Southwest Bay, together with telecommunications cables dating to the late 19^{th} Century. Records indicated that the MILS cables failed primarily at or near the shoreline, where they were encased in split pipe and laid on the seabed.

A large number and wide variety of sources were used to develop the desktop study. These included sources for the bathymetry, geology, and climatology. Numerous sources were found that provided bathymetry contours that cover the areas between Ascension Island and the proposed HDAS locations. Some good quality data are available for a few selected areas around the island, but most of the bathymetry data are based on satellite altimetry analyses, and proved to be somewhat unreliable for selecting sensor sites and cable routes.

The northern HDAS route is about 28 km long. The route heads northwest from South West Bay, crossing 10 km of relatively shallow seabed before turning WNW. The route descends along a spur ridge, where slopes up to 26° may be encountered, to the proposed HDAS location. The southern HDAS route is about 120 km long. The route descends for about 30 km to the base of the island reaching approximately 3000 meters water depth. It then traverses 80 km of relatively flat seabed before climbing to the top of a seamount, the HDAS location, where the water depth was estimated to be 2200 meters.

Various hazards that might affect the HDAS cables and sensor structures were assessed as part of the desktop study. Ascension Island has a geologically recent, volcanic origin, but there are no records of any eruptions on the island since its settlement in the early nineteenth century. Earthquake activity appears to be confined to the Mid-Atlantic Ridge, and there are no tsunamis on record. Turbidity currents and slope failure are possible hazards, although sediment deposits necessary for such events appear to be absent on and around the island. Near-bottom water currents are typically only a few centimeters per second. However, if there are cable spans on rough terrain, such currents can cause the cable to chafe. An objective of the survey of the proposed cable routes was to determine the risk of slope failure and any history of turbidity currents, and to be able to delineate areas of rough seabed. The cable routes can then be realigned to avoid the worst of the hazardous areas. Fisheries, offshore mineral and oil exploration, naval activity and shipping activities were found to be all either absent or of a minor nature and were expected to pose no risk to the cables, nor interfere with survey or installation operations. No known marine archeological sites are present along the proposed cable corridors.

Submarine telecommunication cables dating back to the late nineteenth century are present at Ascension Island, but all cables, including the MILS cables, are now inactive. Crossing these cables does not pose any risk to the HDAS cables.

The climate at Ascension Island is relatively benign, showing very little seasonal variation. Trade winds from the ESE are very stable at about 15 knots, and high winds are uncommon. Temperature varies only slightly around a mean of 26° C (79° F). Tidal range on the island has a maximum of about 1.4 meters (4.6 ft). Wave height and swell height are typically 1 meter and 2 meters, respectively. However, storms in the South Atlantic can result in occasional very large swell conditions, up to 7.5 meters. High swell conditions, typically occurring between June and August, are likely the only climatological issues for survey and installation operations.

4. SEAFLOOR SURVEY

Recent advances in acoustic remote sensing of the seafloor have substantially improved the ability to make accurate maps of the seabed for selecting cable routes and locations for installing undersea sensors. This technology is particularly important for cable route surveys in areas of irregular and steep underwater topography such as that found around volcanic islands, including Ascension Island. This technology provides precisely geo-referenced bathymetry and imagery at the water depths of interest. In addition, it substantially increases the efficiency of the survey operations because the survey can be conducted at two to ten times higher speeds and wider swath widths than traditional methods. Further, since there are no towed devices in the water, this methodology eliminates the potential loss of data due to impact of a towed fish with the bottom or the risk of loss of the towfish. Because of the substantial technical, cost and schedule advantages of this technology, it was selected for the Ascension Island cable route and hydrophone site surveys.

The objectives of the survey were:

1. Identify the best sites for installation of the Ascension Island hydrophone array systems. The criteria for site selection are:
   - acceptable bottom conditions for the hydrophone anchors and system cables
   - bathymetry suitable for buoying the hydrophones into the SOFAR channel.

2. Identify the most secure, lowest risk to survivability and most economically viable marine routes for laying the data cables to the shore landing

The first objective requires a detailed bathymetric map of the two candidate hydrophone installation sites, with imagery of the seafloor. The area to be surveyed was a 20km by 20km box at each of the two sites. The second objective requires bathymetry and imagery of a minimum 2 km wide corridor from the hydrophone sites to shallow water, and smaller survey corridor widths into the shore landing. Sufficiently detailed bathymetry and imagery are required to assure that the routes avoid excessive slopes, strong currents, slumps, and hard or rocky seafloors. Because of the extremely rugged topography offshore Ascension Island, and the requirement for a 20-year system life, it was essential that the bathymetry and imagery be sufficiently detailed to allow confident cable route selection. A comprehensive plan was prepared [6] that specified survey areas and routes, and defined the equipment and processing to be used for the survey.

A detailed geophysical seabed survey for the Hydroacoustic Data Acquisition System (HDAS) project at Ascension Island was conducted by Thales GeoSolutions (Pacific), Inc. The survey was conducted for MCA Engineers, Inc. on behalf of the Naval Facilities Engineering Service Center. The survey took place between June 13 and July 29, 2002 and was completed in two phases, inshore and offshore. The objective of the survey work was to identify suitable routes for two cable installations connecting underwater acoustic monitoring systems with a shore-based data acquisition and transmission facility at Pan Am Beach, Ascension Island.

The inshore survey was carried out from June 12 to June 23, 2002, and extended from the shore facility to about the 50-meter isobath. Data were collected with a single beam echo sounder, sidescan sonar and shallow sub-bottom profiler. This phase also included a land survey between the proposed landfalls to the MILS building and a nearshore diver survey to assess the characteristics of the seabed near the surf zone.

The offshore survey was carried out from July 15 to July 29 and extended from the 30-meter isobath to the proposed locations for the acoustic monitoring arrays. One of these array sites is located approximately 30 km to the northwest of the landfall and the other is approximately 115 km south of Ascension Island. The offshore survey acquired multibeam bathymetry, multibeam backscatter, and shallow sub-bottom data in order to characterize the seabed and identify suitable cable routes.

An example of the data from the survey is shown in Figure 5. This figure shows the seamount selected for the southern acoustic detection system site. These data show the extent and variation of the slopes around the seamount, an important criterion for sensor installation.

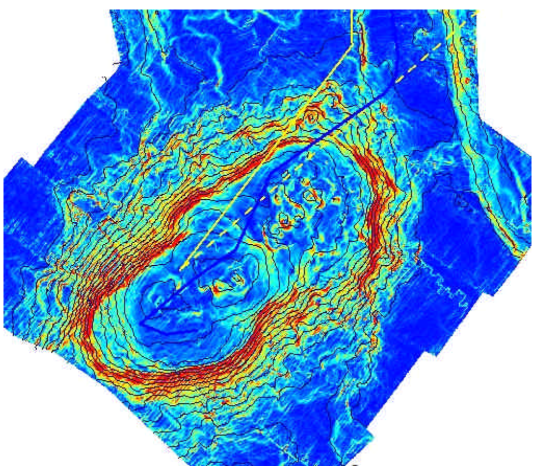

Figure 5
Slope Data for the Southern HDAS Sensor Site

The results of the survey are presented in the survey report, [7].

5. INSTALLATION OF DIRECTIONAL DRILLED BORES

A review of candidate DDB onshore launch sites led to the consideration of three sites at various locations around Southwest Bay. These are shown as Drill Sites A, B, and C in Figure 6.

Results of the site survey and inspection indicated that the site designated Drill Site B is the most desirable. This site is situated at the south end of Southwest Bay.

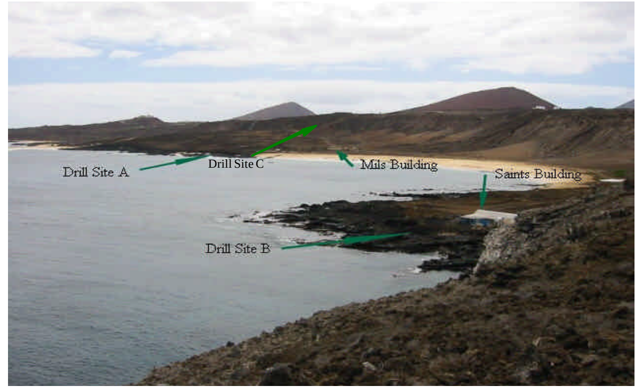

Figure 6
Candidate DDB Sites at Southwest Bay

Drill Site B was selected based on the following considerations.

- The substrate material is more consolidated than at Drill Site A.
- The shoreline geometry places the drill launch point nearer (about 140 feet) to the water line (versus 240 feet at Drill Site A, and a much longer distance at Drill Site C).
- The bathymetric data from the nearshore survey indicated that the 40 foot water depth is located about 300 feet from the shoreline, making the bore length to reach such a depth only 500 feet (versus 1000 feet for Drill Site A).
- There is ample area on stable soil for supporting the drilling equipment at this site.
- There appeared to be no significant reefs or ledges seaward of the proposed DDB exit point (out to at least 70 feet water depth) that would result in cable suspensions or other cable hazards.
- Drill site B is on the leeward side of the bay, so typical shore breaking waves and winds are less than the other sites.

Because of the extremely remote location of Ascension Island and the logistics considerations of getting equipment to the island, a small, mobile drilling rig was required for the DDB operations. A Ditch Witch Model JT4020AT directional drilling rig was used for this operation. This rig is 26 feet long, weighs 21,000 lbs, is self-propelled, and can be airlifted by military cargo planes. The rig is self-contained with its own diesel engine (200 hp John Deere) that supports drilling operations as well as a caterpillar tractor-walk for mobility, has outriggers for stability, a front-end auger system for anchoring the rig during drilling operations, and work lights. Another notable feature is an automated pipe loading/unloading system that expedites the process of building or breaking down the drill string. This rig is the largest model of its class manufactured by

Ditch Witch, and can typically drill boreholes in excess of 1,000 feet. The primary advantage of a larger rig is the greater pull-back force available from the increased horsepower. This larger pull-back force is important because the limiting factor of these machines is typically their ability to pull the conduit back through the borehole.

The objective of the drilling effort was for each borehole to exit the seafloor in a relatively benign region beyond the area of wave action, as identified from the survey. To accomplish this, the drill head was steered to maintain the planned borehole profile. The heading of the drill bit can be adjusted by controlling the orientation of the drill head.

As the drilling progresses, an electro-magnetic tracking instrument is used to measure drill head location, depth, and orientation, providing the data for any needed corrections to the drill operator, who can then adjust his drill direction accordingly.

The complete drilling equipment suite includes the drilling machine with a tracking system, a drilling fluid mixer, and a vacuum unit to recover the spent fluid from the bore.

The drilling process uses bentonite (“mud”), a clay product, for lubricating the drill head and pipe, and for sealing the bore. The Ditch Witch JT4020AT uses an internal shaft to power the drill head, rather than a “mud motor.” This substantially reduces the amount of mud required for the operations, an important consideration for operations at remote sites. The bentonite and drill rod were shipped to AI by vessel. The drill rig was shipped by air.

Three DDBs were installed at Southwest Bay to accommodate three future HDAS cables coming ashore. These cables are for the seawater ground, the north array, and the south array. Figure 6 shows the borehole routes relative to the shoreline and the seafloor imagery data. The boreholes were lined with polyethylene pipe pulled into the bores after the holes were drilled. The ends of the liners were capped to minimize intrusion of seafloor material before installation of the cables. The DDB routes are shown in Figure 7 superposed over the offshore seafloor imagery. The DDB operations are described in detail in [8].

6. Planned Future Operations

The activities required to complete the system installation at Ascension Island include placing the hydrophone systems at the north and south sites, laying the trunk cables back to the island, and bringing the cables ashore through the DDB liners. In addition, the shoreside data processing and transmission equipment will be installed in the termination building.

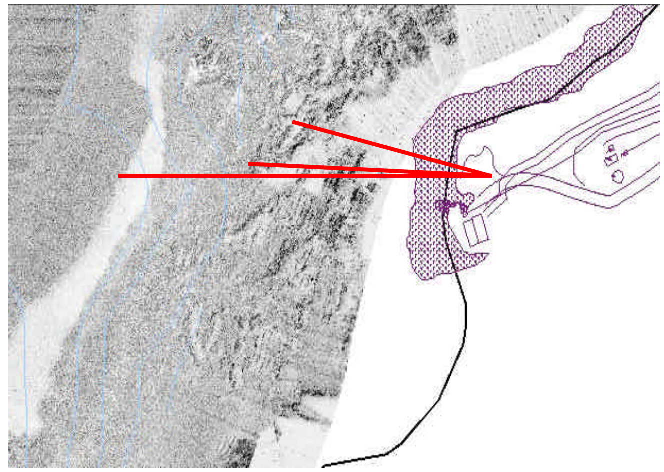

Figure 7
Installed Locations of Ascension Island DDBs

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