Horizontal Directional Drilling
Cable Shorelanding at San Nicolas Island, California

Stan Black P.E.	Brian Cable	Bob Fredrickson, P.E.	David Warren, P.E.
Sound & Sea Technology	NAVFAC Engineering Service Center	NAVFAC Engineering Service Center	NAVFAC Engineering Service Center
2175 Goodyear Ave. Suite 101	1100 23rd Ave. Port	1100 23rd Ave. Port	1100 23rd Ave. Port
Ventura, CA 93003	Hueneme, CA 93043	Hueneme, CA 93043	Hueneme, CA 93043
sblack@soundandsea.com	brian.cable@navy.mil	robert.fredrickson@navy.mil	david.warren1@navy.mil

Abstract – The U.S. Navy used unique construction and deployment methods to install new shorelanding cables at San Nicolas Island, California. The project involved repairing and upgrading an existing cable shorelanding using horizontal directional drilling. As part of the project, three 12-fiber SL21 single armor cables were pulled simultaneously into a 1.1 km (3740 feet) 15.2 cm (6 inch) diameter conduit. While pulling multiple cables into one conduit may be common with terrestrial applications, this process is unique for undersea cable applications, particularly for bores of this length. This paper summarizes the installation methods and environmental benefits of the project.

I. Introduction

San Nicolas Island is owned and operated by the Navy as a major element of the Point Mugu Sea Range. Located approximately 105 kilometers [km] (65 miles) southwest of Point Mugu, California, the island is 14 km (9 miles) long by 6 km (3.6 miles) wide, encompassing approximately 54 square km (21 square miles). The island is extensively instrumented with metric tracking radar, electro-optical devices, telemetry, and communications equipment necessary to support U.S. fleet training and weapons testing. An airfield is located at the southeastern edge of the island's central mesa.

Two subsea fiber-optic cables comprise the main offshore components for a Fiber-Optic Communications Underwater System (FOCUS). Both cables extend from Point Mugu to San Nicolas Island as shown in Figure 1. Due to a history of failures in the near shore environment, in June 2004 the U.S. Navy implemented repairs to the existing FOCUS cables at the island. The much needed repairs were accomplished in 3 phases: 1) Horizontal directional drilling (HDD) was used to install 1.1 km (3,740 feet) of new seashore interface conduit; 2) Conventional construction methods were used to install 11.3 km (37,000 feet) of terrestrial cable; and 3) Three new offshore fiber-optic cable segments (two 7 km cables and one 1.4 km spare cable) were deployed. The two new cables were spliced into the existing FOCUS cables offshore.

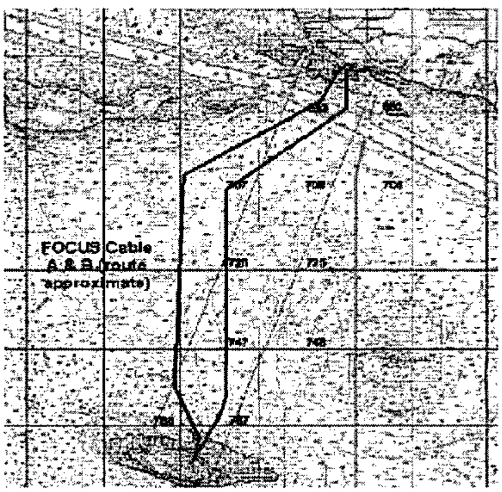

Figure 1. FOCUS Offshore alignment.

II. Background

Installed in 1993 – 1994 time frame, the FOCUS cable system is a critical communications component for Naval Air Warfare Command Sea Range operations. The existing seashore interface conduit (steel tubing) at the island in which the cables were enclosed had reached the end of both its fatigue and corrosion life. Failures in the conduit, as well as in the cables were becoming more frequent and more difficult for maintenance repair activities to keep pace. This was particularly difficult during the winter months when near shore current and wave

0-7803-8669-8/04/$20.00

conditions prevented diving operations to effect repairs.

Radar and telemetry data signals collected at the island are transmitted via the FOCUS cables back to Point Mugu where activities throughout the entire Sea Range are coordinated. The primary data cable (Cable A) provides the main communications fiber-optic link. A secondary cable (Cable B), serves as a back up link. Communications facilitated by the existing FOCUS cables are critical to the daily operation of the 93,240-km^2 (36,000-square-mile) Point Mugu Sea Range; a break in these cables would result in the shutdown of most (if not all) Sea Range operations until the cables are repaired.

The existing conduit system at the island was surface laid (not buried) at the shore landing and was therefore exposed to wave and current energy. The conduit consisted of approximately 1.1 km (3,740 feet) of commercial drill pipe - one conduit for each cable. A multiple of 9 m (30 feet) long pipe sections were threaded/joined and laid on the seafloor as the protective conduit. The water depth at the end of the conduit system was approximately 11 m (35 feet). Due to the shallow water and constant wave action, the system required frequent and costly underwater repairs to maintain stability of the conduit (Ref Fig 2). Cable B had recently failed in the surf zone in a water depth of 4 m (14 feet) – an area that presented extremely challenging repair conditions at best. With the back-up cable down, a failure of Cable A would mean disruption of this vital communications link. Although continued inspections by Navy divers indicated short-term repairs on Cable A were effective, continued exposure to the severe near shore environment could result in a failure at any time. The risk in the near term was high, with a 100% likelihood of a system failure within 5 years. Therefore, a long-term solution was needed to protect the FOCUS cables at the San Nicolas Island near shore environment.

Figure 2. Cable stabilization point.

III. Technical Approach

A new shore landing site was selected approximately 6.4 km (4 miles) from the existing site. The new site was selected to avoid the offshore hard bottom areas such as the area where the existing FOCUS cables were laid. Horizontal directional drilling (HDD) was used to install one new seashore interface conduit for subsequent installation of 3 fiber-optic communication cable segments (2- operational and 1 spare cable). The total length of the HDD bore was approximately 1.1 km (3,740 feet). All 3 cables were installed into the HDD conduit in a single pulling operation. Since the water depths along the new cable segment route range from 26 m (85 feet) to 46 m (150 feet), the new FOCUS cable segments are protected from the strong ocean currents and wave action that occur in the shallow near shore environment (Ref Fig 3.).

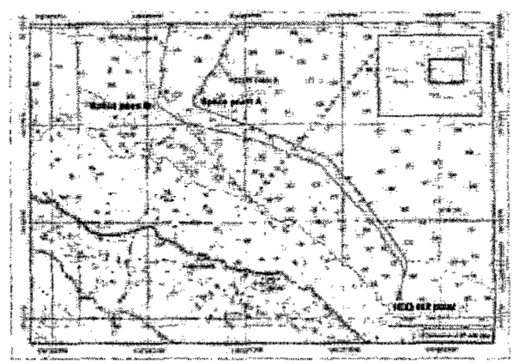

Figure 3. New FOCUS cable routes.

Two of the new offshore cable segments extend approximately 7 km (4.4 miles) from the HDD exit point to the existing cables. At that point the new cables were spliced into the two existing FOCUS cables. The third cable was cut, sealed and left near the HDD exit location as a spare.

A new terrestrial cable segment was installed and connects the existing FOCUS cable infrastructure on the island with the new offshore segment. The new terrestrial cable involved installation of approximately 11.3 km (7 miles) of new cable.

The following sections present an in-depth discussion of the HDD operation, terrestrial cable installation, and the offshore cable deployment. Table 1 provides a summary of these activities.

IV. Siting Criteria for the HDD Shore Landing and Environmental Considerations

HDD operational requirements and environmental limitations were identified in order to develop reasonable location options for the new FOCUS cable segments and to minimize potential environmental effects. Siting options were developed based on the following operational requirements and environmental criteria:

- the drilling site needed to be as close as possible to the shoreline;
- elevation at the drilling site should be as low as possible (< 15 m) above mean sea level) to minimize the angle of drilling and maximize the offshore exit point depth;
- the offshore slope should be as steep as possible in order for the exit point to be as deep as possible;
- there must be a relatively level area for the HDD pad, particularly for the bentonite recycling system;
- the drilling site should, to the extent possible, be located in a previously disturbed area to minimize environmental disruption;
- the drilling site should not be on sand due to difficulties in operating the equipment and because sand would absorb the drilling fluid more quickly, resulting in higher water demand during drilling;
- both the onshore and offshore components of the project should minimize disruption to sensitive natural and cultural resources; and
- the onshore cable conduit system should use existing infrastructure to the maximum extent possible to minimize costs and potential environmental disruption.

Environmental considerations were an extremely important aspect during cable route planning and design of the shore landing. San Nicolas Island is home to a large and diverse variety of animal and plant life. It is one of the major breeding grounds for three species of seals and sea lions, and the coastal zones on the island also provide habitat for several federally protected species. At the FOCUS HDD project site, 3 protected species were prevalent: the Snowy Plover (a beach nesting sea bird), the Channel Island Night Lizard and the California Elephant Seal.

Table 1. Summary of FOCUS Cable Repair Activities

Component	*Size*	*Duration*	*Miscellaneous*
HDD Operations	Drill pad: 30,000 square feet (2,788 m^2) HDD bore hole diameter: 9 inches (23 cm)	21 days (includes setup & demobilization)	Bentonite clay drilling mud pumped into hole during drilling.
Terrestrial Cable Installation	Trench: 20 inches (51 cm) wide by 40 inches (102 cm) deep Cable segment: 0.4 mile (0.6 km) of new trenching and 6.6 miles (10.6 km) of existing conduits	30 days	Use existing conduits in most areas; new cable segment ties into existing utilities.
Offshore Cable Deployment	HDD bore hole segment: 1.2 km. Ocean bottom segment: 7 km.	7 days	3 cables pulled into HDD conduit in single operation

The use of HDD technology greatly reduced the impact to the environment and these animals versus trenching across the beach. By using a HDD bore hole to route the cable under the beach and tidal zone, the breeding Elephant Seals and other wildlife on the beach were totally undisturbed. A portion of the HDD drill pad is shown in Figure 4. Note that the colony of Elephant Seals resting on the sand directly above the drill path remain undisturbed by the drilling operation.

The location of the drill site was chosen in a previously disturbed area to minimize any additional environmental disruption on the island. The location was also chosen to avoid offshore hard bottom areas. Hard bottom or reef areas support a wide variety of marine life. The cable route was designed to avoid these areas to protect marine life and to minimize potential cable damage due to suspensions and abrasion. By laying the cables on sand, the cables eventually partially bury themselves which provides additional protection.

Finally, the manhole (concrete vault) for the onshore cable connections was located away from the beach to avoid Snowy Plover nesting areas. Although this resulted in a more difficult cable pulling operation, it enables year round access to the manhole since Snowy Plover nesting areas are off limits during nesting season.

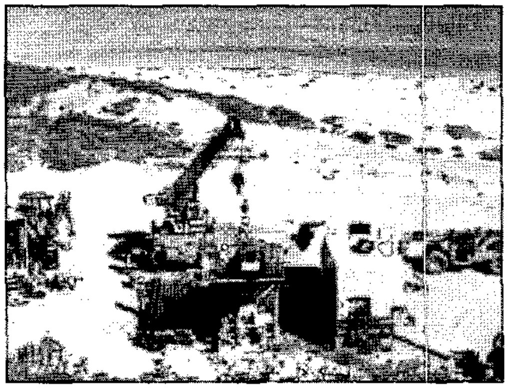

Figure 4. Elephant seal colony on beach during drilling operation.

For the drilling operation itself, a spill prevention plan was developed and followed. This included a bentonite drill-mud management plan, monitoring and recording the use of drill-mud during drilling operations, and a fully mobilized on site spill response vessel present just before and after the drill string exited the seafloor. In addition, water was used in place of the bentonite drill-mud just prior to the drill string exiting the seafloor in order to minimize the release of drill-mud into the ocean.

As a result of these precautions, no adverse environmental impacts were observed.

V. Horizontal Directional Drilling Method

A schematic diagram showing the HDD configuration is shown in Figure 5.

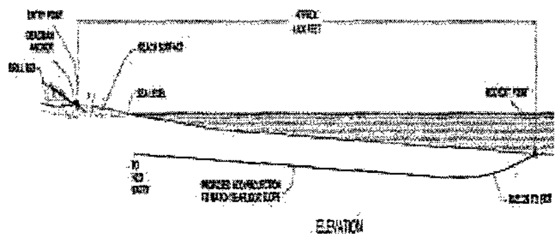

Figure 5. San Nicolas Island horizontal directional drilling profile.

A 1.1 km (3,740 foot) long bore was successfully drilled and lined with a 15 cm (6 inch) dameter steel conduit from shore to the sea floor exit point at a depth of approximately 26 m (85 feet). Cherrington Corporation (Sacramento, CA) accomplished the HDD under contract to Sound & Sea Technology who was the prime contractor. The drilling and conduit installation operation required the shipment of approximately 340,200 kg (375 tons) of equipment by a Navy furnished barge to the island. Major consumables used included 18 pallets of bentonite drilling mud 24,900 kg (27.5 tons), 568,000 liters (150,000 gallons) of water and 3 drill bits. While no major problems were encountered during the drilling operation, a shortage of water on the island (for drilling mud) together with variations in subsurface formation geology resulted in minor delays in completing the bore.

San Nicolas Island has an uplifted geology with a layered sandstone and siltstone structure as shown in Figure 6. The layers are tilted at about 15-20 degrees from horizontal. To assist in bore planning, a single 25.2 m (83 foot) deep core was obtained at the drill site prior to drilling operations. In addition, offshore bathymetry and sub-bottom profiling provided information for establishing a bottom profile along bore and cable deployment routes.

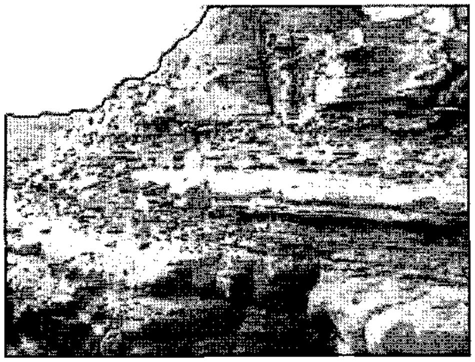

Figure 6. Typical geologic layering at San Nicolas island.

Data from analysis of the core showed sediments to be a combination of siltstone and sandstone with an unconfined compressive strength ranging from 422,000 to 1,125,000 Kgs/m^2 (600 to 1600 psi). At 12.2 m (40 feet) below grade a very hard (3,500,000 to 10,500,000 Kgs/m^2 [5000 to 15000 psi]) layer 1 m thick was encountered.

Cherrington Corporation proposed a single 24.4 cm (9-5/8-inch) diameter bore into which would be pushed a 14.6 cm (5-3/4-inch) inside diameter, and 16.8 cm [6-5/8-inch] outside diameter steel liner. A drilling plan was developed to maintain a shallow radius for the bore path and therefore minimize bending required during insertion of the bore liner. Figure 7 shows the HDD equipment layout.

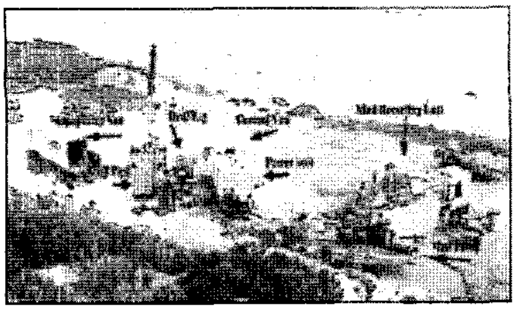

Figure7. San Nicolas Island directional drilling equipment setup.

During the first few days of drilling approximately 125 m (410 feet) per day were completed with nearly 100% return of drilling fluids. Cuttings consisting of small sized (2 to 3 cm diameter) material were being returned to the settling pit. (Ref Figure 8.) The bore was swabbed frequently to ensure a good buildup of bentonite on the bore wall in preparation for later installation of the liner. Along the bore path the formation alternated between siltstone and sandstone.

After the first few days, at 518 m (1700 feet), the drilling rate slowed and the drill string was removed from the bore hole. The bit was found to be severely worn. Three bits were required to complete the bore. For the following 10 days, a combination of high circulation loss and water shortage events slowed drilling. A water expanding polymer was used to seal the bore wall. A water shortage was resolved with delivery of a water barge from the mainland. Prior to the drill string exiting through the sea floor, 91 m (300 feet) of casing was installed to support the drill string during the drilling operation. At 30.4 m (100 feet) from exit, the drill crew switched from bentonite drill-mud to fresh water to minimize the amount of drill-mud leakage on the seafloor. Upon the drill string exiting the seafloor, there was no visible indication of drill-mud in the area of the HDD exit point.

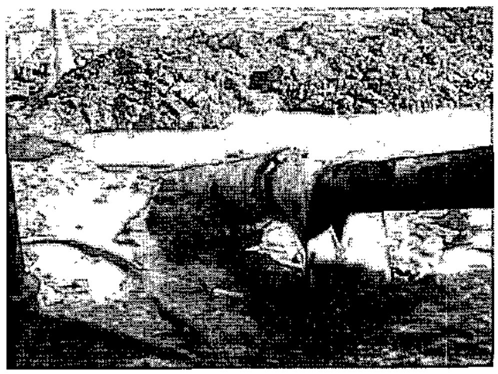

Figure 8. Mud pit at HDD entrance point.

At the exit point, divers found the drill projecting 1.2 m (4 feet) out of the seafloor at approximately 26 m (85 feet) water depth. They cut off the drill bit using Oxy Arc underwater cutting equipment. The final location was within a 4.6 m (15 feet) radius of the planned exit. The drill pipe was then recovered from the bore hole and preparations were completed for insertion of the steel bore liner.

The bore liner consisted of 9.1 m (30 feet) long sections of Permalok, heavy wall steel conduit (16.8 cm [6.625 inch] outside diameter with 1.1 cm [0.432 inch] wall). The "stab" type mechanical joints between each section of conduit (Ref Fig 9) provides a smooth, flush joint that requires between 18,000 to 27,000 Kg force (40,000 to 60,000 pounds) to make the connection. A jetting head was welded to the conduit leading edge to assist in pushing the conduit through the bore hole in the event of an obstruction. However, no jetting was required and the conduit was installed without any problems.

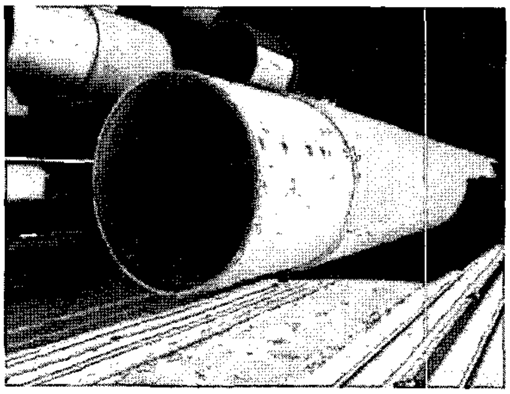

Figure 9. Permalok conduit.

Once the conduit was fully installed through the length of the bore hole, divers located the conduit exit point at the seafloor and removed the jetting tip. A bolted flange and pumping chamber was mounted on the shore end of the conduit for a proofing pig and messenger line installation. The pig was inserted in the pipe and a messenger line was attached to a swivel on the pig. The recovered pig showed no damage, indicating that the bore was clear of obstructions or snag points. The divers then secured the end of the tag line and capped the underwater conduit.

VI. Terrestrial Cable Installation

The FOCUS terrestrial cable effort involved installation of approximately 11.2 km (37,000 feet) of new 48-fiber cable. This includes approximately 93 m (304 feet) of flange connected steel pipe to span the distance between the HDD conduit and the terrestrial manhole. This section of conduit included three bent pipe sections and included angles of 15, 20 and 30 degrees to reach the manhole. A 3-meter radius was used for each bent section to minimize the required tension during the cable pulling operation. Site geometry for this section is shown in Fig 10.

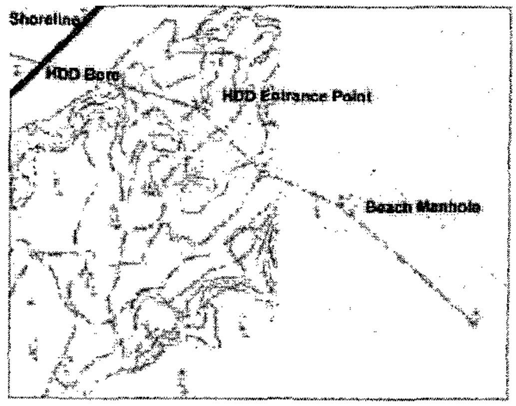

Figure 10. Onshore Conduit Route.

From the FOCUS manhole near the HDD site to the island Range Communications building, approximately 10.7 km (35,000 feet) of existing above and below ground conduit was utilized. This included using abandoned fuel and water pipelines. Because the existing terrestrial conduit infrastructure was extensive, the completed installation required only 609 m (2,000 feet) of below-grade construction (trenching) to make the final terrestrial connection – a significant reduction in both construction cost and environmental impact. The terrestrial cable is a continuous unit without intermediate splices.

VIII. Offshore Cable Deployment

With the HDD conduit in place, the offshore cable installation was ready to begin. Offshore cable operations included 1) pulling of cables through the HDD conduit, 2) laying of approximately 15 km (50,000 feet) of submarine cable, and 3) splicing of the new cable into the existing FOCUS cable system. The total time required to complete the offshore operations was seven days.

The M/V Independence (Ref Fig 11), operated by MAR, Inc, was used as the installation vessel. The M/V Independence is a Government-Owned Contractor Operated vessel. The vessel is 61 m (200 feet) long, has a 12.2 m (40 feet) beam, and an 3.3 m (11 feet) draft. The Independence is a medium-sized workboat with dynamic-positioning and a working deck area of approximately 278 m^2 (3000 ft^2). Due to the complexity of the three-cable deployment operation and the quantity of equipment required on the deck, a creative deck layout was needed to perform the cable deployment.

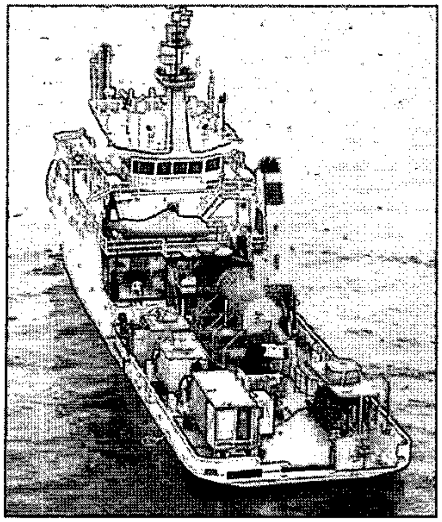

Figure 11. M/V Independence

The three cables were pulled simultaneously from the ship to the island through the single conduit. This presented one of the most challenging aspects of the cable deployment. Both diver and ROV services were used to assist the initial alignment, rigging, and pulling of the cable through the conduit. Divers from MARIPRO in Goleta, CA attached a custom bellmouth to the offshore end of the conduit to insure the cables would maintain minimum bend radius requirements as they were pulled through the conduit. The divers also rigged the pulling hardware used to pull the cable through the conduit to the island. A SEABOTIX mini ROV was used to monitor the cable as it entered the bellmouth during pulling operations. The SEABOTIX video camera enabled the linear cable engine operator to maintain the optimum catenary on the three-cable assembly as it was pulled into the bellmouth. The ship remained stationary near the conduit exit point as the three cables were pulled simultaneously from the ship to the island using a tractor on the island end.

Pulling tensions were measured during the cable pulling process and were compared to predicted values. The actual versus predicted pulling tensions are summarized in Figure 12.

The following equation was use to predict tension values.

$$(1)\ T = mu \times w \times L \times CF \times 3$$ [1]

where

T = tension
CF = coefficient of friction along straight conduit
w = weight per unit length
L = pull length
mu = friction factor at bent sections.

Furthermore, values for *CF* and *mu* were based on the following:

$CF = 0.45$

and

for 15 degree bend, $mu = 1.08$
for 20 degree bend, $mu = 1.20$
for 30 degree bend, $mu = 1.30$.

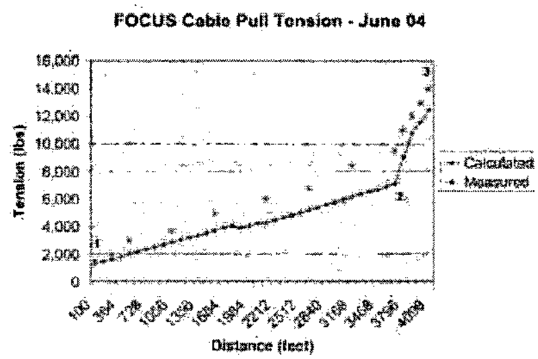

Figure 12. Cable pull tension versus distance.

Calculated tension values were very close to measured values as can be seen in Fig. 12. The "1" in Figure 12 is the offshore entry point for the cable, and "3" is the terrestrial end of the conduit. As predicted, the pulling tension increased significantly when the cable bundle reached the onshore bent pipe sections, indicated by "2" in Figure 12.

After the cables were safely through the conduit and the cable ends were accessible on the beach, the ship began cable deployment operations. MAKAI Plan software was used to plan the cable routes and Winfrog software was used for navigation and cable deployment management. Cable deployment was accomplished using a Caley Linear Cable Engine (LCE) (Ref Fig 13) and an over-boarding chute. Cable was stowed in two 3.6 m (12-feet) diameter portable cable pans and one powered cable reel. Fairleads were used to redirect the cable from each location and align to the LCE. The cable

[1] Based on industry standards

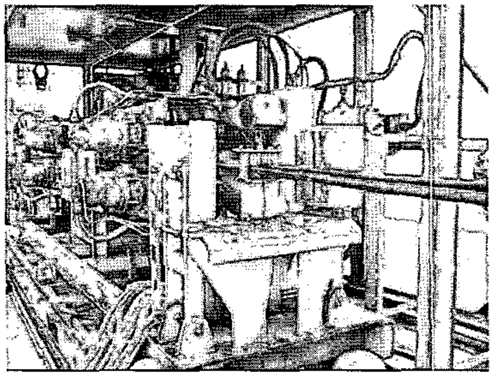

Figure 13. Caley Linear Cable Engine (LCE)

engine was fitted with custom fingers to maintain separation between cables during the initial deployment of the three cables.

Shortly after cable laying commenced, two of the three cables were cut, sealed and deployed at pre-planned positions near the HDD exit - one cable would eventually get joined to the active FOCUS A system, and the other cable was a spare. The third cable remained continuous and was deployed for approximately 7 km (23,000 feet) where it was joined with the FOCUS B system.

A PHANTOM ROV was used to recover the cable from the seabed for splicing. Due to the close proximity of existing FOCUS cables A and B, ROV recovery was selected over standard grappling operations. The PHANTOM snapped a Spectra line on to the cable and the cable was recovered to the ship. The Spectra line was then transferred from the Phantom to a shipboard winch and a cable bight was pulled to the surface for splicing.

After the FOCUS B cable was joined and brought online, the FOCUS A cable was connected by splicing a new 7 km (23,000 feet) segment of cable between the cut cable near the conduit exit and the active FOCUS A cable.

Cable joining was accomplished in a modified 20-foot ISO container by a joining team from TYCO (Baltimore and Eatontown, N.J.). Each cable joint included 12-fibers and took approximately 16 hours to complete. Due to limited deck space, the joining van had a slot cut in one end to allow a cable bight to extend out of the van. This enabled the active area of the joint to be centered in the van, with the joint tails extending out of each end of the van.

The existing FOCUS cable was a relatively old variant of SIMPLEX SL 1001. The FOCUS system is un-repeatered and un-powered, so the original FOCUS cable was manufactured without the standard dielectric properties. This cable has a similar core as the TYCO SL-21, however the unified fiber structure is a Hytrel matrix design, and the core has only a thin HDPE belt. Approximately 20 km (65,000 feet) of new cable was required to make the repair on both cables. Since the old FOCUS cable was no longer produced and unavailable for this repair, a modified Universal Quick Joint (UQJ) was developed by TYCO to mate the old FOCUS cable to new TYCO SL-21L Light-Wire Armor (LWA). While these cables mated-up well in size and strength, there were subtle differences that required developing and testing a new UQJ variant. Challenges with the new joint included three different fiber types and two different armor packages, however the splicing operations were completed successfully.

IIX. Summary and Conclusions

Horizontal directional drilling was used to install one new seashore interface conduit for subsequent installation of three fiber-optic communication cable segments. The total length of the HDD bore was approximately 1,140 m (3,740 feet). The three SL21 cables were installed into the HDD conduit in a single pulling operation. This technique of using only one bore hole/conduit resulted in a significant reduction in the overall environmental impact, as well as greatly reducing overall cost of the project.

The new shore landing provides FOCUS the maximum protection possible from ocean currents and wave action that occur in the shallow near shore environment.