LAYING IT ON THE LINE AT BOTH ENDS OF THE WORLD

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Abstract: This paper discusses how Alcatel-Lucent Submarine Networks (ASN) addressed some specific marine installation challenges in the Southern and Northern hemispheres, where identifying, planning for, managing and minimising the many and varied risk factors was vital for the success of the cable installations. The ultimate aim on all projects is of course to install the cable within its design parameters and to the Customer's requirements, and the variety and severity of potential risks can be greater on the shorter, shallower water projects. To achieve the optimum installation, even after good risk identification, mitigation and thorough preparation, can still demand "on the job" flexibility and creativity, to adjust the operations as necessary to cope with unforeseen issues, as will be shown in this paper.

1 SOUTHERN HEMISPHERE

The Magellan Strait at the southern tip of South America is located at 52 degrees south. It experiences extremes in climatic and oceanographic conditions, with frequent storm force winds throughout the year, diurnal (twice daily) tidal ranges of 7m to 9m, tidal currents up to 9 knots during peak flows and very short durations of slack (calm) waters. The tidal currents and ranges are some of the greatest found anywhere on Earth. In 2012 we faced the challenge of installing three cables in this area. One cable linked the Argentina mainland to Tierra del Fuego at the Atlantic gateway of the Strait (the "Argentine project"), and two cables crossed the "2nd Narrows" within the eastern sector of the Strait linking Chile to Tierra Del Fuego (the "Chilean Project").

While close geographically, the challenges faced during the two projects were both similar and also significantly different, but certainly falling far outside the norms of "standard" cable projects.

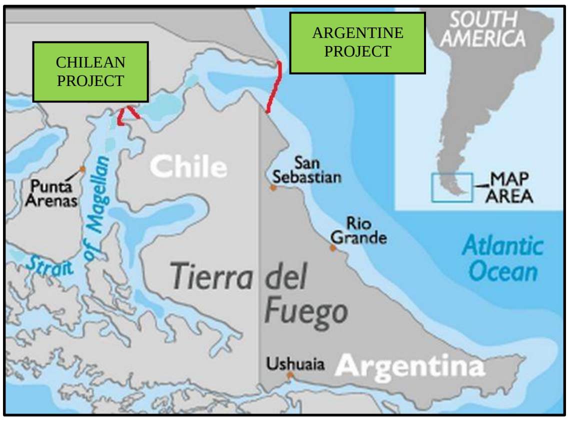

Figure A: The Three Cable Routes (in red)

The remoteness of the region was a major factor, the Magellan Strait being 2,200km south of Santiago and Buenos Aires, with Antarctica being far closer at only 1,300km further south! This meant a requirement for long transits by the mainlay ship to simply get to the cable grounds, and the need for thorough planning so that full autonomy for the installation operations would be possible.

Optimised operational methods were used to ensure the three cable laying operations combated the severe conditions that were striving to push the cable off-line, and the six shore-end landings were successfully completed in possibly the most challenging conditions imaginable.

Part 1 – The Argentine Project

The Argentinean cable project consisted of a single 35km unrepeatered cable connecting Punta Dungeness on the northern mainland to Espiritu Santo on Tierra del Fuego.

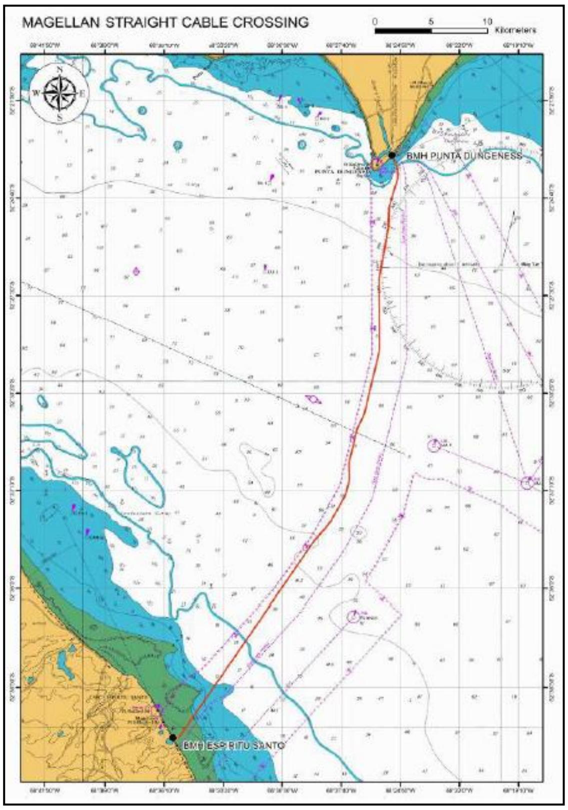

Figure B: The Argentinean Cable Route (in red)

The installation strategy for the system was for a double armoured cable plough buried to 1.5m target depth. In addition, at the Espiritu Santo shore-end, 2m burial depth to the 20m water depth (LAT) was required, and this had to lie within a 10m wide by 2m deep "dredged trench" that had been backfilled with sediments. From a cable protection point of view, the rationale to dredge a 2m deep trench through the locally hard seabed and backfill it with softer sediments made good sense, as it would optimise the cable burial potential. However, from a shore-end installation point of view, having to make sure the cable was laid into such a narrow channel would make the whole operation considerably more difficult than normal! This was even more so when considering that this location has a 9m tidal range and 2-3 knots of current at peak tidal flows. In addition, the shallow seabed slope meant the 20m depth contour was 6.5km offshore, so floating and accurately lowering such a long section of cable to the seabed along the dredged channel line was a major concern and installation risk factor.

The achieve success the strategy was to maximize the use of the cableship and minimise the cable pulling and diver burial distances. This meant taking the cableship to a holding position in only 10m (LAT) water depth, while normally the standard holding position would be at 12m-15m water depth (the cableship draft is 8.5m). This resulted in a 3km shore-end pull, which although much shorter than 6.5km, was still the longest cable-pull performed by ASN in such a dynamic tidal and climatic area. With the cable landed ashore, the cableship waited for high tide and then moved further shorewards to the 8m water depth (LAT), at 2.8km from the beach, and starting plough burial there. In essence, by using the huge tidal range, even with the plough-down location at 8m depth LAT, the real water depth at plough deployment time was 15m, this being the minimum limit of safe plough deployment for our vessels (any shallower and the ship's hull could strike the top of the plough). The 2m burial was achieved by the cableship in the offshore shore-end section (from KP2.8 to KP6.5), with diver burial shoreward. By using divers only in the shallow areas, the diving safety was also maximised, which is even more important than usual due to the remoteness of this area.

Figure C: 3km shore-end pull at Espiritu Santo

For Punta Dungeness, at the northern end of the cable lay, the shore-end landing challenges were nearly the reverse of those at Espiritu Santo. Here the choice of landing location was very limited, as the BMH had to be located between the Chilean border, only a few hundred metres to the west, and a Penguin Nature Reserve, only a few hundred metres to the East. In effect, there was no choice in landing location, and so the steeply shelving spit that forms Punta Dungeness had to be used. The major concern for this landing was the strong tidal flows, because the spit forms a barrier to the tidal currents that flow in and out of the Magellan Strait. As a result, right at the landing location the tidal currents are greatly accelerated, increasing the demands on the cableship for holding position. In addition, the predominant south westerly wind is blowing in a landward direction here, trying to push the ship onto the Punta Dungeness beach itself. With these factors at play, it was some blessing that the actual distance for the shore-end cable pull would only be short, as the steeply shelving seabed meant the 15m depth contour was only 350m from shore.

As it turned out, on the day of the Punta Dungeness shore-end landing a relatively rare event occurred, as the near constant gale force winds that dominate this region relented and allowed the landing to be performed in perfectly calm conditions, with the cableship only 210m from the beach – one of the shortest cable pulls in our history. This was certainly proof that even with all the planning in the world, sometimes it also helps for a bit of luck to be your side!

Figure D: 210m shore-end pull at Punta Dungeness

Part 2 - The Chilean Project

The two unrepeatered cables installed in the Chilean part of the Magellan Strait were 12km long (Cabo Gregorio to Segunda Angostura), and 18km long (Cerro Cono to Cabo San Vincente). They were both laid across the "2nd Narrows" of the Magellan Strait, which is situated 60km east from the port of Punta Arenas, in the eastern sector of the Strait. While initially planned for plough burial, the lack of sediments in this area meant they were both surface laid onto the seabed.

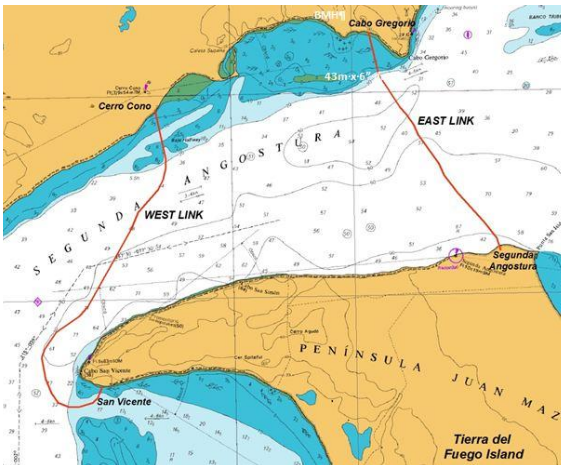

Figure E: The Two Chilean Routes

The choice of routing across these 2nd Narrows, instead of crossing the wider and calmer parts of the Strait, was driven by the need to find suitable landfall locations. Along many parts of the Magellan Strait it was not possible to find suitable beach conditions, with correspondingly suitable land access points for linking to the terrestrial back-haul routes. As a result, from 14 sites visited during the site visit activities (by travelling many 100's of miles on unmade roads and rough terrain), only 4 locations were considered suitable to meet the system design and installation requirements.

Figure F: The Cliffs along the Magellan Straits

While this routing across the 2nd Narrows was suitable for the system connectivity issue, it was absolutely not ideal from a marine installation point of view, due to the extreme tidal conditions experienced at these Narrows. Because the Magellan Strait links the Pacific and Atlantic oceans, and due to its high latitude location at 52 degrees south, there is a very dynamic tidal regime in place that twice daily forces a huge amount of water between these two Oceans. In addition, at the 2nd Narrows, the tidal flows are accelerated even further as they are squeezed by the narrowing channel, with ferocious currents of up to 9 knots (nearly 17kmh). This "squeezing effect" accelerates the water and also forces it upwards, therefore increasing the tidal range during peak flows, with 8-9m tidal heights recorded here.

In essence, the 2nd Narrows of the Magellan Strait are more similar to a mountain river than a classical marine cable laying environment, although even there the comparison does not give the full picture of the ferocity of the site. For a true comparison the mountain river would need to totally reverse its direction of flow and rise and fall by 9m on a twice daily basis, while also experiencing gale force winds that near-constantly blow across the Magellan Strait! By all measures, this is an area of extreme conditions.

The main risks these conditions put on the cable laying activities were related to the ability of the cableship to maintain position. This was especially the case during each shore-end landing, when the vessel needed to hold station using its dynamic positioning systems to control the ship's propellers, tunnel & azimuth thrusters while the cable was pulled ashore. This was done successfully at all four cable landings, with a zero-error requirement on both the vessel capabilities and also those of the ship's crew.

For the main cable laying activities, the ability for the vessel to accurately lay the cable on-line while traversing across the Strait's tidal currents required the dynamic positioning system to allow her to "crab" along the route (e.g. lay the cable while moving sideways, instead of forwards).

This careful positioning was done by balancing the thrusting propulsion power of the vessel against the forcing vectors acting against it from the wind and tidal currents, all of which were in constant flux during the lay due to the ever changing state of the tidal cycle and wind strengths. Simultaneously, the onboard cable machinery had to carefully control the rate of cable pay-out to ensure that the cable was laid on-line and to the tension specifications required.

The relative shortness of the cable routes meant laying durations were very short, taking only one day for each cable. This meant rapid back-to-back shore-end landing activities, and a need for a "two-team" approach, one for the two northern landings and one for the two southern landings. For each cable landing operation the timing of slack water was targeted to limit the risk of the cable running offline, while the length of each pull was minimised, with the cableship coming as close to shore as possible. The pulling operations were done using small boats with messenger lines and excavators on the beach, and at three of the four landings the cable was landed ashore and safely cut-down to the seabed in a single operation.

However, for the Cerro Cono landing, due to the long cable pull of 2.4km and the extremely high tidal currents, it was necessary to perform the shore-end landing in two stages. First, the cable was pulled ashore as normal at slack water, but due to the quickly rising currents the cable cut-down activity could not be commenced immediately. With the divers unable to stay in position in the water, the cable tension rising and daylight fading, a decision was made to postpone the cut-down operation until the following day, requiring the cableship to hold position overnight as the tidal regime went through an entire cycle. This meant a 2.4km floating cable bight was present between the cableship and the landing for the duration of the night, with tensions rising to 12.2 tonnes at the peak tidal flow (still within the cable design specifications), before eventually easing as daybreak approached the next day. During the short time of slack water, the cable bight was eased back online and the divers performed the cut-down operation as usual, eventually completing the shore-end landing nearly 24hrs after it had started. The high power and dynamic positioning capability of the cableship and the skill of the crew meant they were able to maintain full control and positioning to enable the in-specification installation of the cable.

Figure G: Floats left on cable for 24hrs landing

The installation of the three cables on this "southern adventure" overcame unprecedented challenges with respect to the location remoteness and the risks involved in cable laying through some of the most extreme tidal conditions on earth. Through thorough planning, good execution, the responsiveness and creativity of the people and full use of the capabilities of the cableship and her crew, as well as a small degree of luck when the weather conditions sometimes relented, it was possible to triumph over extreme adversity in order to deliver these systems safely to the Customers.

2 NORTHERN HEMISPHERE

The challenges faced in the Northern hemisphere were more operational than environmental related. In the two cases described, marine resources were already committed, and in the first case marine installation operations were already ongoing at sea.

Case 1:

A last-minute requirement was received from an owner of a non-telecom underwater resource during the lay operation. In order not to delay the operation by waiting for the extra protection normally needed to implement the requirement, an innovative solution was developed which made use of the existing quantity of protection that was on board. New operational techniques and procedures were developed to rise to the challenge faced. Very often innovation occurs when backs are against the wall.

There are many variables to be considered when engineering cable protection, which makes accurate positioning extremely difficult. The protection must be applied shipboard several water-depths away from the crossing point, based upon an estimated touchdown point on the seabed. This touchdown point is determined by the shape of the cable catenary to the seabed, and is influenced real time by factors such as ship movement, cable pay-out, cable tension and underwater currents.

As such the touchdown position for a given cable position shipboard is difficult to predict, especially in deep water. So the normal approach is to increase the length of protection applied to ensure good cover.

Given all the constraints on this occasion, following much consultation, the “out-of-the-box” approach was to calibrate the cable’s lay over the crossing.

Beacons were sourced and applied to the cable, so that the cableship could monitor the cable’s touchdown point by the planned cable crossing. A sound velocity profiler (SVP) was first deployed a safe distance away from the crossing, then a buoyancy beacon, in order to assess beacon position accuracy and currents. Then the buoyancy beacon was fitted to the cable at the theoretical crossing position and deployed over the crossing.

Once on the seabed, the beacon’s position was measured at three different cableship headings to find an average position and best cableship heading. The offset of the beacon from the theoretical cable crossing position was calculated using the cableship’s bespoke lay software. The beacon configuration used is shown in Figure 1 and the calibration results in Figure 2 (where the red diamond is the average of the green diamonds at different cableship headings).

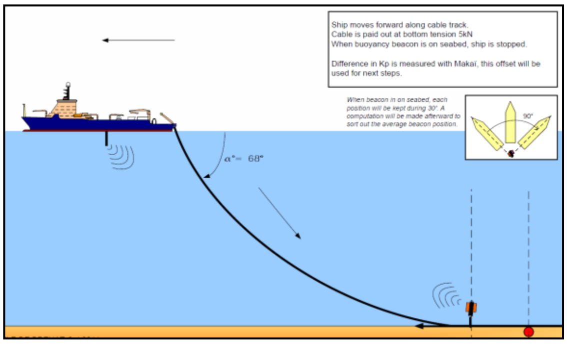

Figure 1: Buoyancy beacon arrangement

The available plastic protection was then applied to the cable at its predicted touchdown crossing position, with beacons attached for monitoring shipboard, as shown in Figure 3. Two different types of beacon were used to provide better coverage. The outcome was that the plastic protection was laid correctly first time, lying within 10m of target and fully covering the cable crossing, as shown from beacon positions measured shipboard (Figure 4) and later verified by ROV (Figure 5), who recovered the beacons.

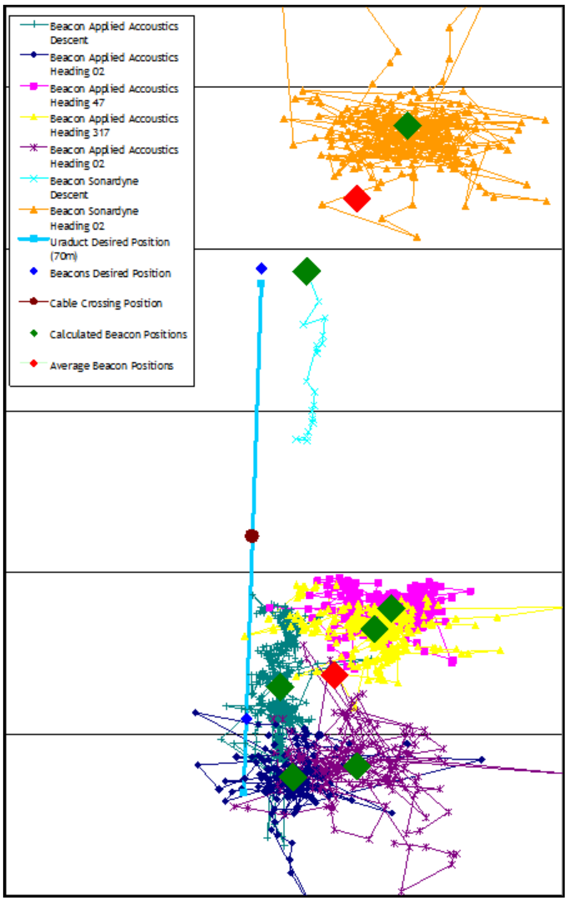

Figure 2: Beacon calibration results

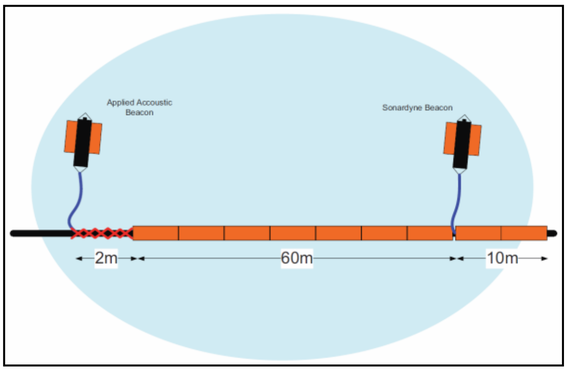

Figure 3: Beacon arrangement

It should be appreciated that perfect weather, and the cableship's sophistication and expertise, were significant factors in getting it right first time. But just as important was the creativity and initiative of the people involved.

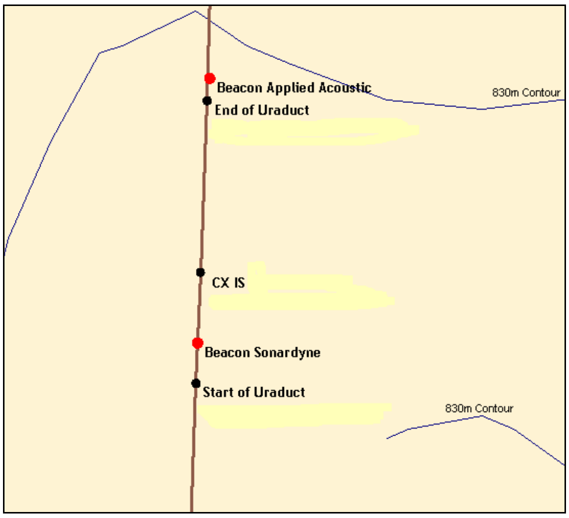

Figure 4: As-laid result

Figure 5: As-surveyed result

Case 2:

Whereas Case 1 related to positional accuracy along the route, Case 2 related to positional accuracy across the route, between fixed points. This time it was important to avoid known pipeline joints some tens of metre apart.

The key factor in this process was the accurate determination of the relative position of the pipeline anodes and joints in relation to the cableship and cable, using the same coordinate system. In this case the measurement system most appropriately available was that of a remotely-operated-vehicle (ROV), in support of the main lay vessel.

An added consideration was that the pipeline crossing point was in a nominally buried pipeline section, potentially masking the position of its anodes and joints. Consequently, identification of a nearby unburied reference anode was added as contingency, to allow correlation.

The ROV preparation prior to works included SVP measurement and USBL spin test (for calibration purposes), as-laid cable inspection (for correlation purposes) and optimised Obstacle Avoidance Sonar (OAS) set-up (for safety).

The ROV works included pre-lay survey of the cable route across the pipeline, including the position of the pipeline joints and anodes (to avoid), also the reference anode, to calibrate the relative ROV and pipeline systems. The pipeline survey plan is shown in Figure 6.

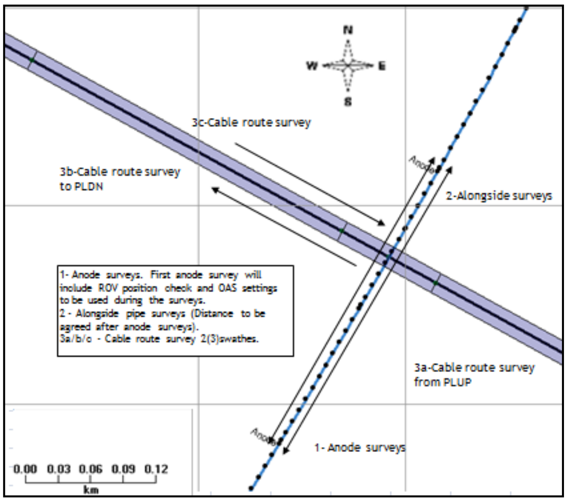

Figure 6: Pipeline Survey plan

The calibration elements provided confidence in the cableship's positional system and layback calculations. ROV post-lay survey of the as-laid cable across the pipeline then proved the cable lay was within a few metres of planned.

Confidence in the ROV positioning system, and its reproducibility, was key in addressing another significant characteristic of the area in question, namely old ordinance in the area.

Whilst the cable route survey had been able to identify suspect sonar contacts, their exact nature was unknown. With expert help, these were visually assessed by ROV, approached carefully using OAS. In this way they were accurately mapped with the same system to be used in lay.

A safe surface lay corridor was established by this contact avoidance process. The survey technique developed and utilised (Figure 7) proved more than adequate.

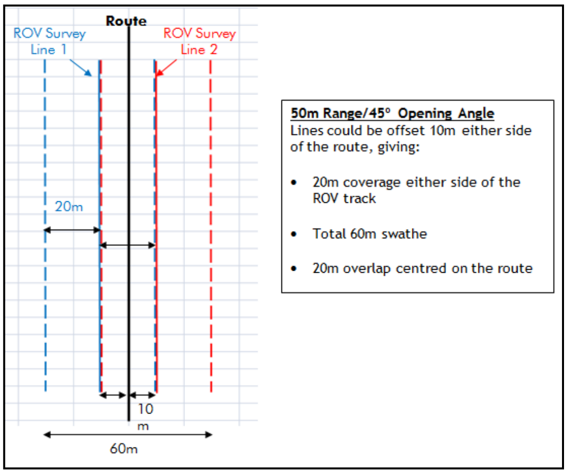

Figure 7: Safe corridor survey

In fact, any munitions detected (Figure 8) were successfully avoided by re-route, using the same proving process.

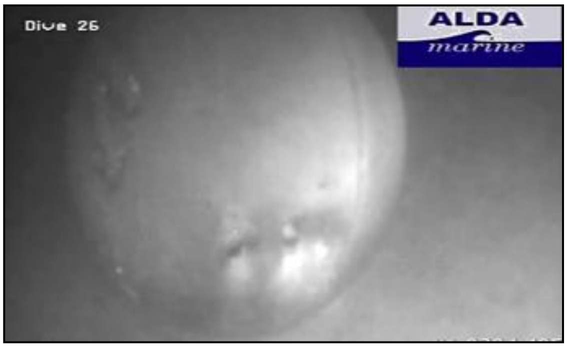

Figure 8: Example of munitions found

The Authors would like to thank Alcatel-Lucent for permission to submit this paper, and to all their colleagues in ASN and ALDA for the constructive comments.

No references are provided in order to preserve the anonymity of these live cable systems.