Welcome back HA03

Robinson Crusoe Island

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In 2010 a tsunami destroyed hydroacoustic station HA03 at Robinson Crusoe Island, Chile. HA03 is part of a global network of monitoring stations established by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). After a huge logistical and engineering undertaking which took four years and cost over US$ 20 million, HA03 is now back in operation.

THE HYDROACOUSTIC NETWORK

The hydroacoustic network is part of the International Monitoring System (IMS). When complete, the IMS will comprise 321 stations and 16 radionuclide laboratories to monitor the globe for evidence of a nuclear explosion. In order to provide uniform coverage, many stations are located in remote areas; this has posed engineering challenges unprecedented in the history of arms control. The IMS uses four complementary verification methods – hydroacoustic, seismic, infrasound and radionuclide monitoring – and incorporates the most modern technologies available.

As sound propagates very efficiently through water, only a few hydroacoustic stations are required to provide effective acoustic monitoring of the world's oceans, thereby ensuring that no nuclear explosion goes undetected. Ten of the 11 hydroacoustic network stations have already been certified as complying with the stringent technical requirements of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Of the 11 hydroacoustic stations, five are T-phase stations. They use seismometers to detect waterborne signals from acoustic events which couple to the Earth's crust in coastal areas. The other six are cabled stations that utilize hydrophones, like HA03. All the cabled stations have two triplets of underwater hydrophones suspended in the water column in a horizontal triangular configuration with a separation of two kilometres, except for HA01 at Cape Leeuwin which has only one.

The names and locations of the triplets for the cabled hydrophone hydroacoustic stations are shown in the table on page 19 (Figure 1). Station HA04 is to be installed in the Crozet Islands.

The deployment depth of the hydrophones changes with location; they are floated at the depth which provides optimal sound propagation conditions at each site. The three hydrophone configuration allows for a bearing estimation of the sounds detected. The

The installation vessel was a modern sub-sea telecommunications cable ship.

hydrophone sensors detect signals in the 1–100 Hz frequency range. The self-noise of the system is 10 decibels below ocean noise for a typically quiet ocean to maximize the detection range of the hydroacoustic network. The signals acquired from the underwater hydrophones of cabled stations generally pass through tens of kilometres of underwater trunk cable to a shore station and from there via a satellite link to Vienna.

HA03 AND THE 2010 TSUNAMI DEVASTATION

The Juan Fernandez archipelago is situated around 670 kilometres west of the Chilean mainland. There

LOCATION AND STATE RESPONSIBLE	STATION CODE	LATITUDE (DEG. N)	LONGITUDE (DEG. E)	HYDROPHONE DEPTH (M)	WATER DEPTH (M)
CAPE LEEUWIN, AUSTRALIA	HA01W	-34.892	114.153	1055	1558
JUAN FERNANDEZ ISLANDS, CHILE North triplet	HA03N	-33.449	-78.938	820	2000
South triplet	HA03S	-33.823	-78.846	810	2100
BIOT/CHAGOS ISLANDS, UK North triplet	HA08N	-6.342	71.014	1250	2300
South triplet	HA08S	-7.645	72.474	1350	1800
ASCENSION ISLAND, USA North triplet	HA10N	-7.845	-14.480	847	2005
South triplet	HA10S	-8.941	-14.648	860	1733
WAKE ISLAND, USA North triplet	HA11N	19.713	166.891	750	1400
South triplet	HA11S	18.508	166.702	750	1150

Figure 1. The CTBTO's hydrophone hydroacoustic stations and their triplets. HA04 is to be installed in the Crozet Islands.

Figure 2. The CTBTO's network of 11 hydroacoustic stations. Stations in red are the hydrophone cabled stations and those in black are the T-phase stations.

are three islands in this archipelago: Alejandro Selkirk, which is the largest and most westerly island, named after the castaway Scottish sailor who actually inspired Daniel Defoe's famous novel 'Robinson Crusoe'; the tiny uninhabited island of Santa Clara; and Robinson Crusoe Island where two CTBTO stations have been installed: hydroacoustic station HA03 and infrasound station IS14.

On 27 February 2010, a tsunami induced by an 8.8 magnitude earthquake hit the island and destroyed HA03 and the central recording facility (CRF) shared by the two stations (the other components of the infrasound station were not affected as they are located on the top of mountains hundreds of metres above sea level). The tsunami destroyed most of the coastal village of San Juan Bautista and claimed 16 lives. Four years later, in parallel with the re-building of the San Juan Bautista shoreline, the CRF and the hydroacoustic station have been fully re-established.

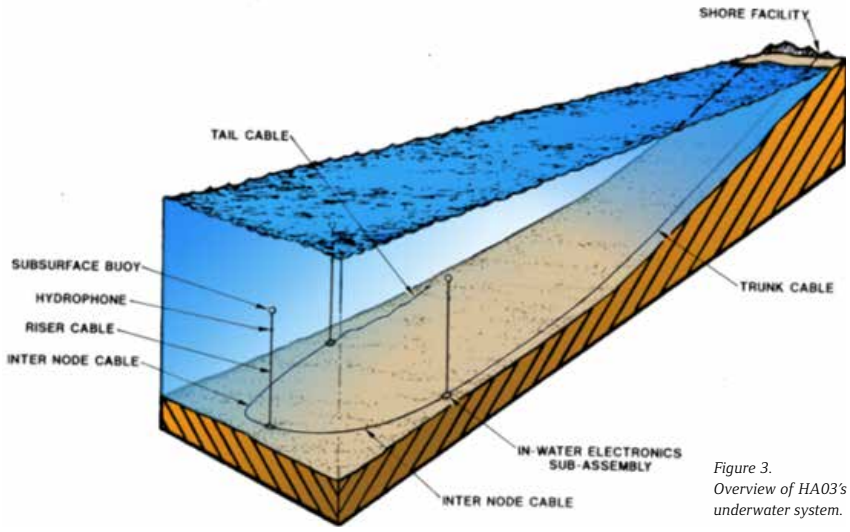
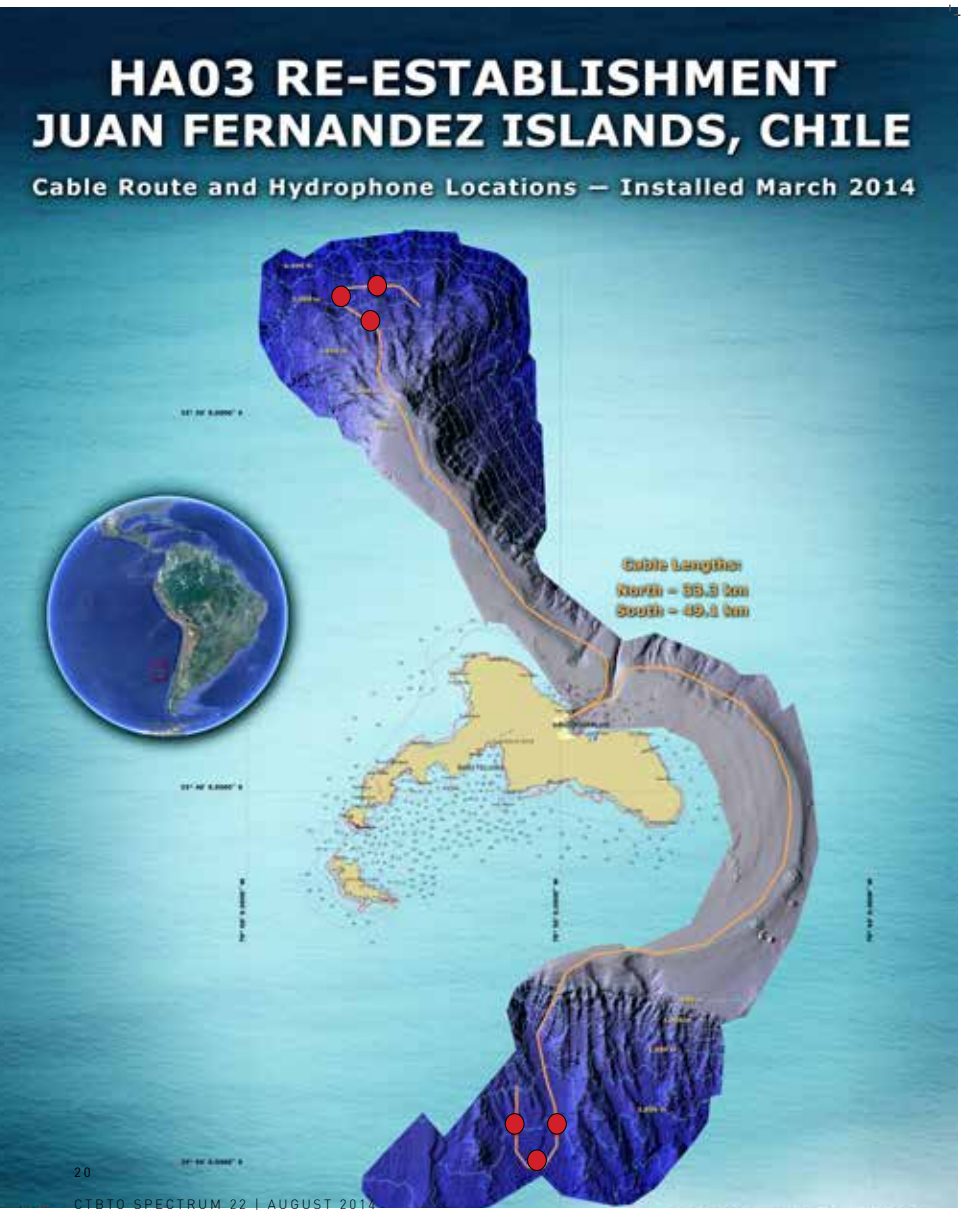


Figure 3.
Overview of HA03's underwater system.



THE RE-ESTABLISHMENT OF HA03 IN 2014

The installation of HA03 consisted of three main phases. First of all, a suitable plot of land for the CRF was identified in the village of San Juan Bautista; its relatively high elevation above sea level is important for tsunami risk mitigation. The CRF was installed in April 2013 and provides the data link for HA03 and IS14 to the CTBTO's International Data Centre (IDC) in Vienna.

The second phase entailed the manufacturing and integration testing of the HA03 system, which was completed in December 2013.

During the third phase from 26 February to 5 March 2014, the underwater system was deployed (see Figure 3).

Figure 4.
A schematic of the underwater cables and the position of the hydrophones with a map of the undersea topography around part of the island. The cables leading to the north and south hydrophone triplets (represented by orange lines) were 33 km and 49 km long respectively, with armouring and other protection applied to mitigate against risks from anchoring and local lobster fishing activities. The hydroacoustic moorings and the location of the hydrophones are represented by red dots.

Deployment of a hydrophone mooring in rough seas.

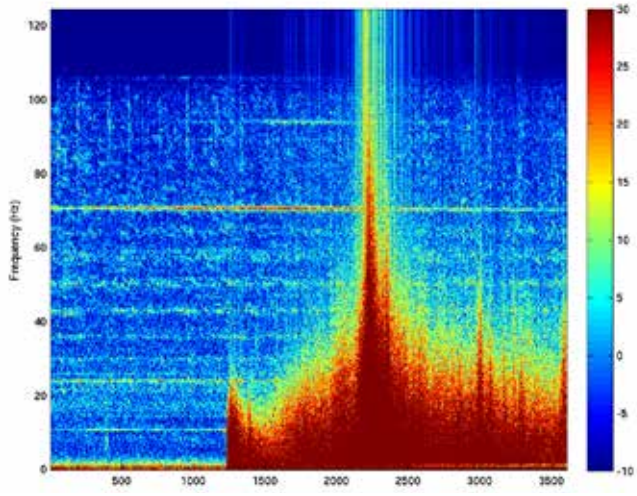


Figure 5.
Frequency content of the 1 April 2014 earthquake signal on an HA03 hydrophone versus time (in seconds) on the horizontal axis. The colour scale is in decibels (dB), with red colours denoting higher energy content.

The CTBTO's system acceptance testing took place immediately after HA03's installation and was completed on 10 March 2014.

Deploying a system of this kind at sea is a complex operation, which differs in many ways from standard undersea telecommunications cable deployment activities. It is a challenge even for the most modern cable ships and experienced teams. The installation was performed flawlessly by an experienced deployment team and the ship's crew who had to contend with some adverse conditions, such as rough seas and wind speeds of more than 30 knots (56 km/h) during some stages of the installation of the north triplet. Immediately after being connected to the CRF, HA03 started sending high quality data to the IDC in Vienna.

PERFORMANCE OF THE NEWLY ESTABLISHED STATION HA03

The quality of the data arriving from the new HA03 hydrophones has been assessed and monitored continuously since the hydrophone nodes touched down at their designated locations on the sea floor. This was made possible through the early real-time connection established during deployment between the station's shore equipment on the island, the underwater system, and the IDC in Vienna. Data from the IDC were sent back by satellite e-mail link to the installation ship and provided immediate feedback about the correct functioning of the system to the installation team.

From day one, HA03 detected a multitude of natural signals of interest, which made it possible to assess that the station was operating to the best of expectations. In addition to providing insights into the functioning of the station, the natural signals recorded are of wider scientific interest, and will be made available to researchers through the virtual Data Exploitation Centre (vDEC) system[1] at the CTBTO or their respective National Data Centres.

One major natural event detected by the newly installed HA03 was the 8.2 magnitude earthquake which occurred on 1 April 2014 in Northern Chile. The first of the fast seismic waves travelling through the Earth's crust below the ocean and leaking acoustic energy into the water can be seen reaching the hydrophone at approximately 1300 seconds in Figure 5. Most of the acoustic energy was contained in the sound radiated from the epicentre into the water near the coast which arrived later at approximately 2200 seconds. The waterborne sound generated by the earthquake was observed by HA03 to come from exactly the direction predicted on the basis of the event's epicentre.

In addition, a large number of underwater explosion-like signals arrived

[1] vDEC is a platform that enables researchers to access archived monitoring data and processing software

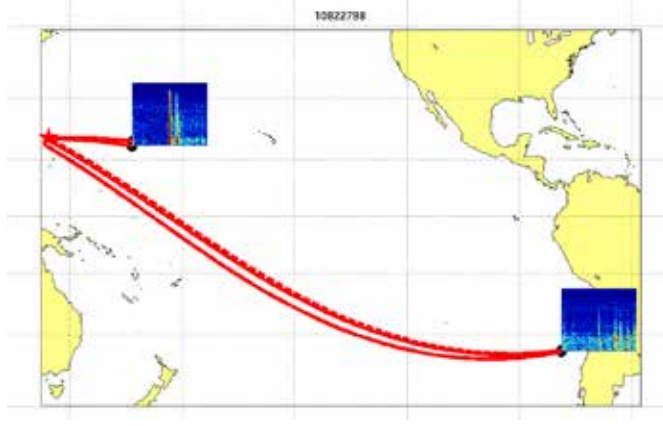


Figure 6.
Frequency content of the hydrophone recordings at HA03 and HA11 pertaining to bursting underwater gas bubbles emitted by an undersea volcano near the Mariana Islands. The paths (in red) indicate the path travelled by the sound to reach the stations.

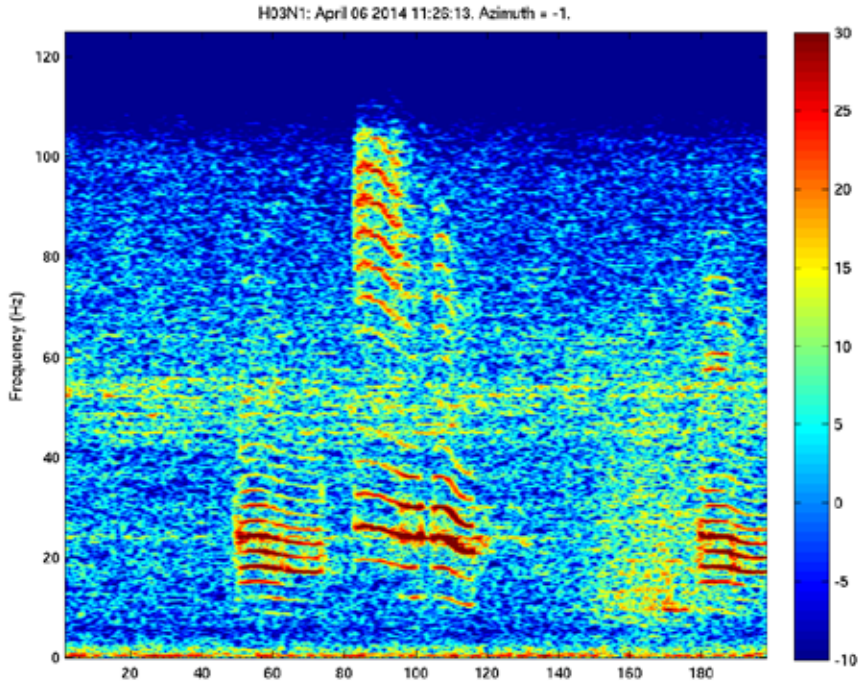


Figure 7.
A spectrogram of a whale's 'song' recorded by HA03.

at HA03 and were registered by the IDC in April 2014. These sounds were generated by bursting underwater gas bubbles emitted by an undersea volcano near the Mariana Islands in the North Pacific Ocean, 15,000 km from Robinson Crusoe Island (see figure 6).

The ocean around Robinson Crusoe Island is characterized by the strong presence of large whales. The whales' calls are in the frequency band of the hydroacoustic station (see Figure 7). Whales swimming towards the hydrophone triplets have been tracked by determining the direction of their calls.

Systematic checks to confirm the correct functioning of the station are conducted on a continuous basis. These checks evaluate the background noise levels recorded by the hydrophones and are compared against average ambient noise curves for the oceans. They are also used to compare HA03's performance with other hydrophone stations.

A MAJOR FEAT FOR THE CTBTO

The reconstruction of HA03 means large parts of the South Pacific Ocean are once again monitored by the station. This major accomplishment for the CTBTO has been made possible through the continuous support of the organization's Member States.

In cooperation with United Nations Television, the CTBTO is producing a video on how its dedicated staff completed the complex and demanding reconstruction of HA03, a station located in one of world's most remote and fascinating islands.

BIOGRAPHICAL NOTES

GEORGIOS HARALABUS
is the Head of the Hydroacoustic Unit at the CTBTO's International Monitoring System (IMS) Division. He joined the CTBTO in 2009. Prior to this he worked for 13 years as Programme Manager at the NATO Centre for Maritime Research and Experimentation in Italy, mainly for the development of Environmentally Adaptive Sonar Concepts. Dr Haralabus is a Fellow of the Hellenic Institute of Acoustics and a member of the European Acoustics Association.

LUCIE PAUTET
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JERRY STANLEY
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MARIO ZAMPOLLI
is a Hydroacoustic Officer/ Engineer with the CTBTO's IMS Division. He joined the CTBTO in 2012 after 11 years at the NATO Centre for Maritime Research and Experimentation in Italy and The Netherlands Organization for Applied Scientific Research. In 2010 Dr Zampolli was awarded the A.B. Wood Medal by the Institute of Acoustics. He is a Fellow of the Acoustical Society of America.