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# Progress in the Studies on the Next Generation Cabled IMS Hydroacoustic Stations.

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**In 2016, a study on the design of the next generation cabled hydroacoustic (HA) stations was conducted with the objective of evaluating viable architectures for the sensor package of the underwater system (UWS) [1].**

**The goals of this project were to:**
**(i) improve sustainability by reducing the impact of events that may negatively affect data availability, (ii) facilitate reparability through modular designs and (iii) develop options for non-interfering instrumentation able to improve the scientific value of International Monitoring System's (IMS) hydroacoustic data.**

**The overriding requirements for all proposed concepts were the minimum 20-year design life and the fulfilment of all other CTBT operational manual specifications.**

**Wet- and dry-mateable connector technologies which have a proven track record in ocean engineering, make it possible to introduce different levels of modularity in order to achieve the above goals. The range of technical solution options that emerged from the study are presented together with the trade-offs vis-à-vis technical/operational complexity and related risks. The successive steps envisaged for this effort are the down-selection of options to fully meet CTBT operational manual specifications and extensive prototype testing.**

## The cabled hydrophone HA stations of the IMS

The IMS is comprised of six hydrophone HA monitoring stations, shown in Figure 1. Apart from HA01 Cape Leeuwin (Australia), which has one triplet, the other five hydrophone stations have two triplets of hydrophones, one to the North and one to the South of the island, to prevent local acoustic blockage.

The direction of arrival of a signal is established by triangulation, using the delays between the arrival times at the three hydrophones of the triplet.

Each triplet is connected to the Central Recording Facility (CRF) at the shore via an electro-optical trunk cable, which provides power to the hydrophone nodes of the triplet and the data-link for the transmission of the digital hydrophone signal to Vienna via satellite. In the current design, the hydrophone signal is digitized at the base of the most shoreward node (Node 1).

| Hydrophone Station | | Water depth (m) | Hydrophone depth (m) |
|---|---|---|---|
| HA01 | W | 1550 | 1100 |
| HA03 | N | 1866 | 824 |
| | S | 2071 | 830 |
| HA04 | N | 1310 | 541 |
| | S | 1309 | 535 |
| HA08 | N | 2300 | 1250 |
| | S | 1800 | 1350 |
| HA10 | N | 2000 | 850 |
| | S | 1700 | 850 |
| HA11 | N | 1400 | 750 |
| | S | 1150 | 750 |

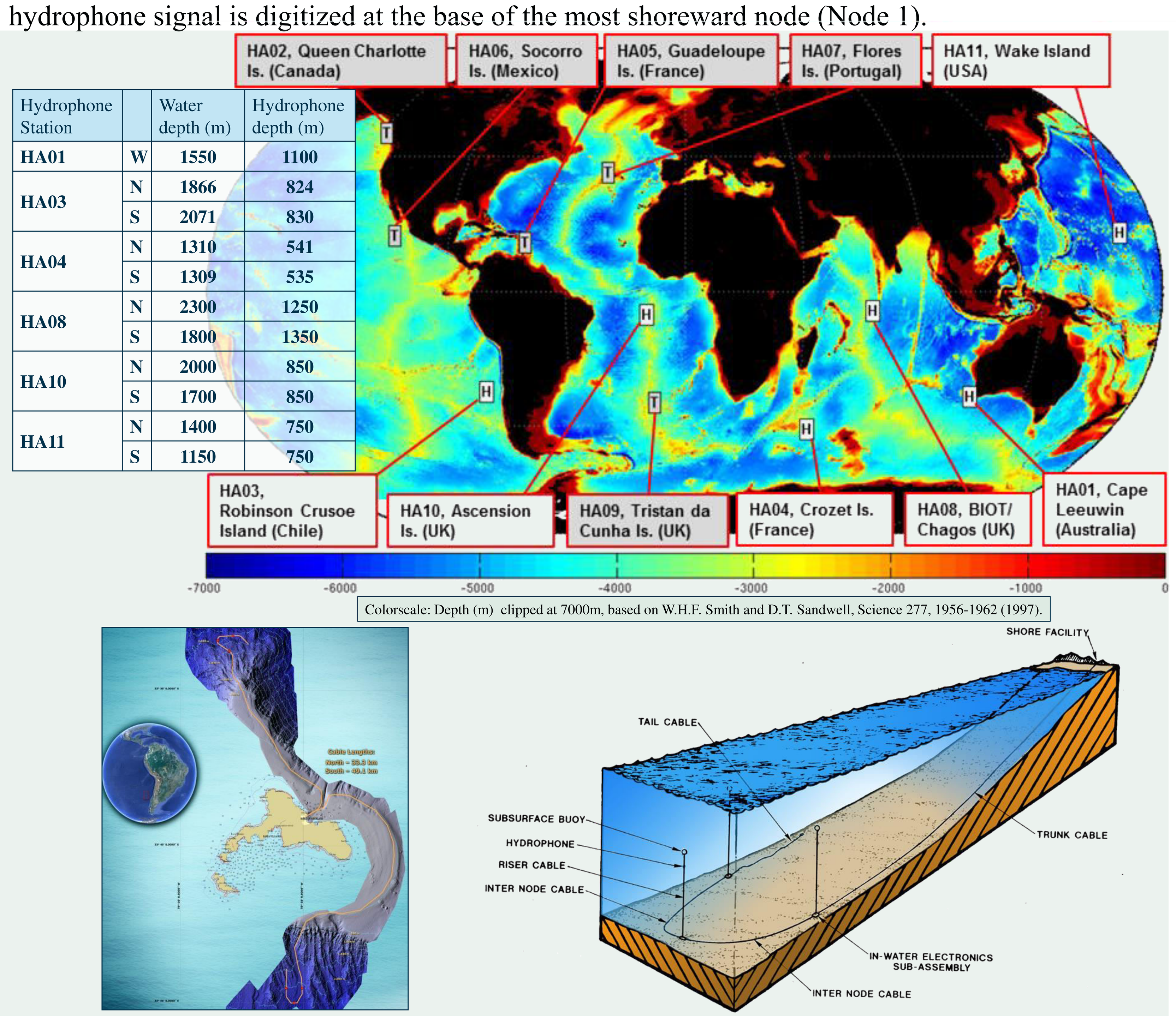


Figure 1. *[Top] The IMS hydroacoustic network, consisting of cabled hydrophone stations (labelled with the letter H) and land-based seismometer T-stations. [Bottom Left] Example of a cabled HA station (HA03), with two hydrophone triplets to prevent acoustic shadowing by the island bathymetry. [Bottom Right] Schematic of a cabled HA station UWS (both bottom images courtesy of L-3 MariPro, Inc., USA). The triplet topology is linear, with the analog-to-digital conversion of all channels occurring in the most shoreward node (Node 1).*

## Modular design options

The study [1] identified five principal failure modes relevant to the sustainability and reparability of HA station hydrophone triplets:

1) Trunk cable failure near the electronics node
2) Main electronics housing failure
3) Internode cable failure
4) Riser / hydrophone element failure
5) Crosstalk between hydrophone channels.

The present design makes use of connectors which are assembled before deployment, and which do not allow wet-mating (i.e. no connections and disconnections underwater). The resolution of any of the five failure modes outlined above essentially requires the recovery of the entire triplet. In terms of sustainability and reparability, the need to remove triplet components which are not directly affected by a failure, translates into a higher risk, longer repair missions and higher repair costs.

**Six Modular Design Options, labelled OPT-1a, OPT-1b, OPT-2a, OPT-2b, OPT-3 and OPT-4 emerged from the study. Each of these options makes it possible to address the above five failure modes on an affected node without the need to move or recover the remaining UWS system components.**

The key ingredient enabling this improvement is wet-mateable connector (WMC) technology. Two types of WMC are available:

i. Electrical WMC's can only be used to mate/de-mate electrical connections. These components are widely used by the Ocean Observatory community and by the Oil and Gas industry, with more than 100,000 units of the most common models sold.

ii. Hybrid WMC's can be used to mate/de-mate electrical and optical connections. In order to enable the highly accurate fiber-to-fiber optical connections, these connectors are more complex and expensive than their electrical only counterparts. The number of mating/de-mating cycles for which these units are qualified is approximately one order of magnitude lower than for electrical WMC's. Nevertheless, these more recently developed components are finding widespread use in the Ocean Observatory and Oil and Gas applications, with several thousands of units sold.

The mating and de-mating of WMC's underwater requires the use of a Remotely Operated undersea Vehicle (ROV), similar to the one shown in the inset of Figure 2. An ROV must be launched and operated from a ship that is equipped with sufficiently accurate Dynamic Positioning (DP).

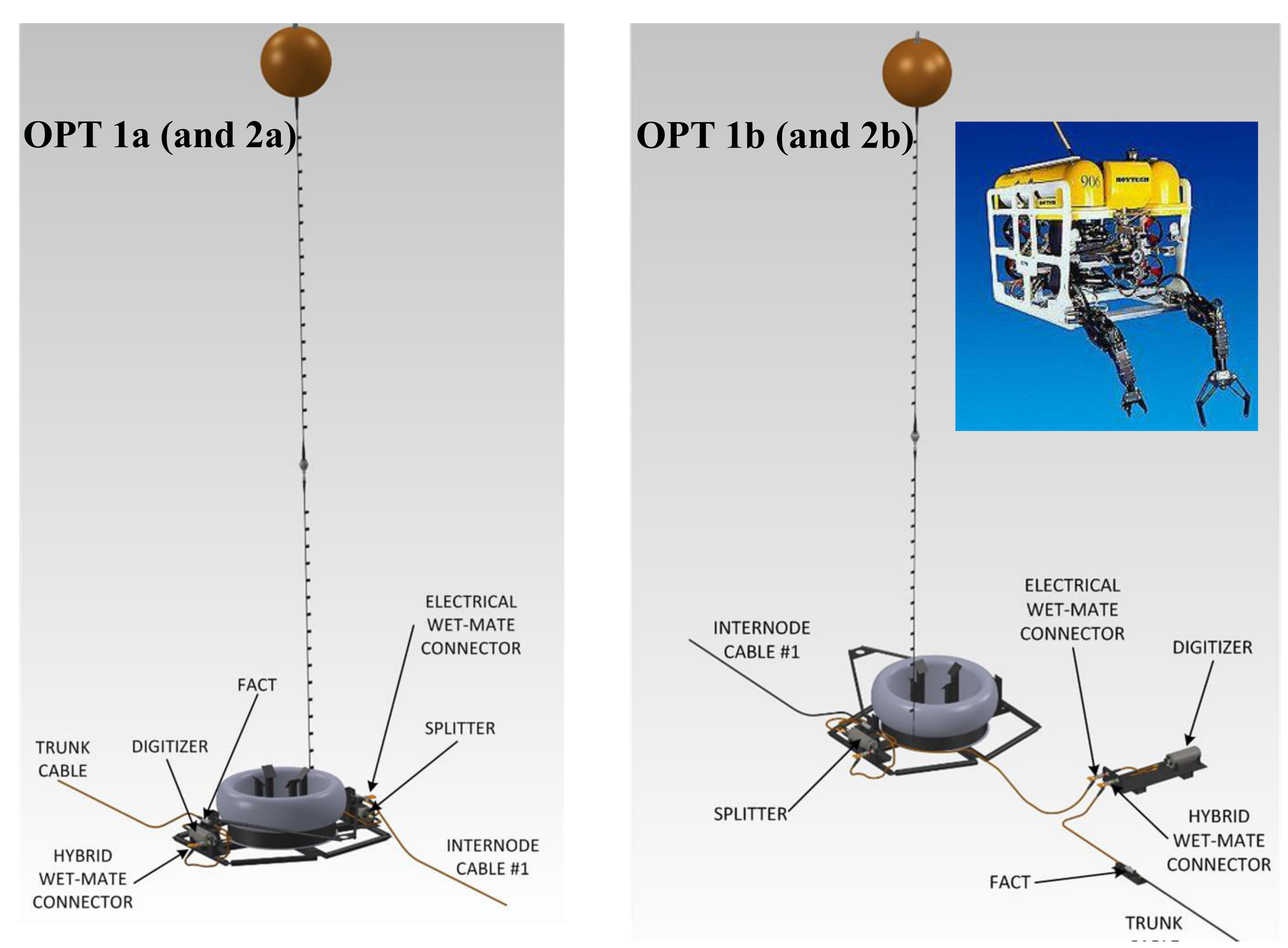


Figure 2. *[Left] OPT-1a concept for Node 1 of a linear triplet. [Right] In OPT-1b , the modular components are separated from the node structure. OPT-2a and 2b are obtained by adding a wet-mateable RS-485 or Ethernet DSL connection to the Digitizer assembly of OPT-1a and 1b, respectively. OPT-1a and 2a can be deployed without the use of an ROV (shown in the inset). OPT-2a and 2b instead allow for less complex repair operations to replace a failed component, compared to OPT-1a and 1b, but require an ROV also for deployment.*

Figures 2 and 3 show concept schematics (not actual design drawings) of the Modular Design options. Variants of OPT-1a and OPT-1b, termed OPT-2a and OPT-2b respectively, enable the connection of non-interfering additional instruments (such as redundant hydrophone nodes or scientific equipment), through an RS-485 or an Ethernet DSL connection at the main electronics/digitizer housing.

Similarly to the present IMS hydrophone stations, the triplet topology of OPT-1a, 1b, 2a and 2b is still linear, with analog-to-digital conversion occurring in one main electronics housing at base of the most shoreward node (Node 1).

OPT-3 depicted in Figure 3, instead, leads to a hub-and-spoke topology, in which all data channels are connected to a central junction box. This option allows for enhanced connectivity of additional instrumentation. OPT-4 is a variant of OPT-3 that would allow to connect a wide variety of science instruments via a high power junction box similar to the those used in Ocean Observatories.

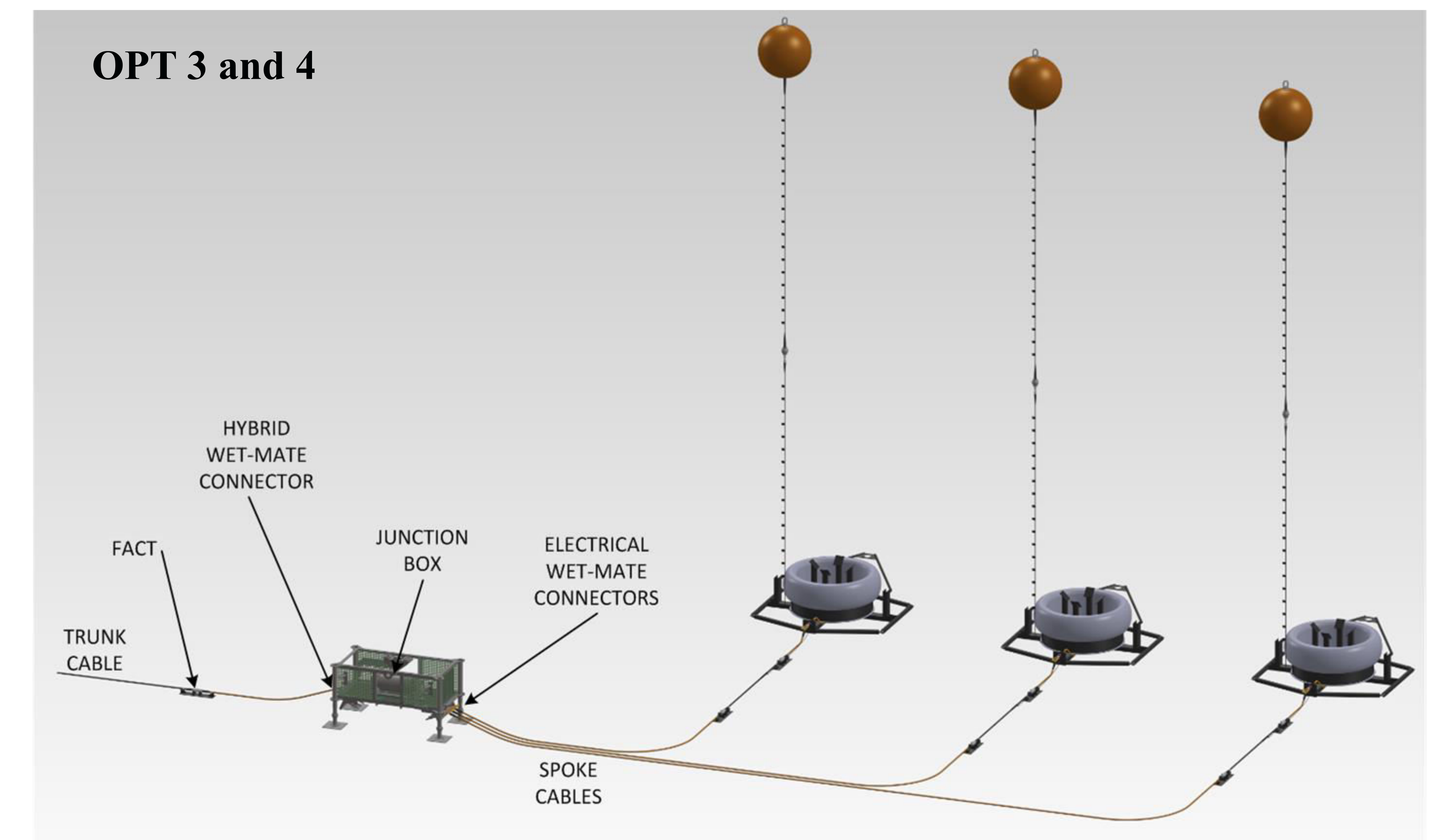


Figure 3. *Concept for OPT-3 and OPT-4 HA triplets with hub-and-spoke topology. OPT-4 would involve a junction box capable of converting down the high-power supplied by the trunk cable for those instruments, like hydrophones, which have low power requirements. Modularity and the associated reparability and expandability are maximized with these Modular Design Options. However, extensive ROV use is necessary for deployment and repairs.*

## Tradeoffs *vis-à-vis* complexity and risks

Modular designs are within reach for future IMS hydrophone HA station repair or recapitalization projects. However, the time to maturity, the operational and technical complexity and additional benefits, such as expandability, need to be carefully balanced with complexity and risks.

| | HA01 | HA03 | HA04 | HA08 | HA10 | HA11 |
|---|---|---|---|---|---|---|
| January | 2.5 – 3 | 3 – 3.5 | 3.5 – 4 | 1 – 1.5 | 1.5 – 2 | 2.5 – 3 |
| March | 2.5 – 3 | 3 – 3.5 | 3.5 – 4 | 1 – 1.5 | 1.5 – 2 | 2.5 – 3 |
| May | 3 – 3.5 | 3 – 3.5 | 4.5 – 5 | 1.5 – 2 | 1.5 – 2 | 1.5 – 2 |
| July | 3.5 – 4 | 3 – 3.5 | 5 – 5.5 | 2.5 – 3 | 2 – 2.5 | 1.5 – 2 |
| September | 3.5 – 4 | 3 – 3.5 | 4.5 – 5 | 2 – 2.5 | 1.5 – 2 | 1.5 – 2 |
| November | 2.5 – 3 | 3 – 3.5 | 3.5 – 4 | 1.5 – 2 | 1.5 – 2 | 2 – 2.5 |

Table 1. *Mean significant wave height at HA station locations (metres).*

A key aspect which must also to be considered in this regard is the risk associated with ROV operations in the ocean conditions that prevail at the different IMS HA station sites (Table 1).

Table 2 shows the main tradeoffs that have been identified for the modular design options. In line with the CTBTO Medium Term Strategy 2018–2021, the insights provided by this analysis will guide the development and testing of HA triplets whose maintenance is both cost-effective and manageable.

| | Modular Design Option | | | | | |
|---|---|---|---|---|---|---|
| | OPT-1a | OPT-2a | OPT-1b | OPT-2b | OPT-3 | OPT-4 |
| Time to maturity/ Costs | SHORT/ LOW | SHORT/ LOW | MEDIUM | MEDIUM | LONG/ HIGH | LONG/ HIGH |
| Installation complexity | LOW | LOW | MEDIUM | MEDIUM | MEDIUM | MEDIUM |
| Repair complexity | MEDIUM | MEDIUM | MED/LOW | MED/LOW | LOW | LOW |
| Technological complexity | LOW | MEDIUM | LOW | MEDIUM | HIGH | HIGH |

Table 2. *High-level tradeoff table showing the relative comparison between the HA Modular Design Options.*

**References**:
[1] G.S. Cram, M.J. Harrington, K.L. Williams, "Desktop Study on Improving Sustainability, Maintainability and Data Availability of CTBTO Hydrophone Hydroacoustic Stations," *Final Report, Applied Physics Laboratory, University of Washington, Seattle, USA* (2016) submitted under CTBTO Contract Ref. No. 2015 – 1589.