P-ONE second pathfinder mission: STRAW-b

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The basic concept:

Pacific Ocean Neutrino Experiment (P-ONE) [1] collaboration is focusing on building a new large-scale neutrino telescope in the Pacific Ocean, at 2600 m b.s.l. in Cascadia Basin, off Vancouver Island. The feasibility study towards P-ONE and the characterization of the optical properties of the site moved from the first pathfinder STRAW (STRing for Absorption length in Water) [2] deployed in 2018, to a second one named STRAW-b deployed in summer 2020, connected to the underwater Ocean Networks Canada [3] infrastructure about 40 meters away from STRAW. STRAW-b aims to validate the *attenuation length* already measured by STRAW besides studying the deep sea diffused light *spectrum*. We present all the steps from the design to the realization of the mooring, with a special focus on the adopted technologies.

Scientific goal:

- **Complementary measurement of *attenuation* length**
- **Characterise the light background spectrum (*bioluminescence* and ^{40}K)**
- testing optical fibre communication to the modules
- complementing the environmental measurements of STRAW
- further characterisation of the site in terms of water quality and backgrounds

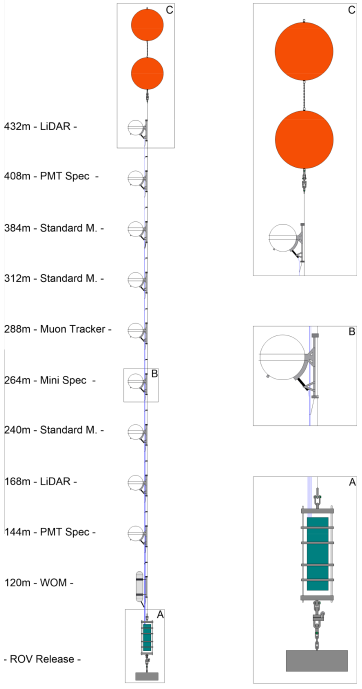
Design:

- 450 m length electrical-optical cable detector with 10 modules
- **3 Standard Modules**- environmental monitoring (pressure, temperature, humidity): their electronics and internal modular mechanical substructure act like the base to which couple the Specialised Modules equipment and their electronic boards. They are used to check the positions of all the modules, using magnetic field sensors and accelerometers.
- **7 Specialised Modules**- background light analysis:
  2 PMT spectrometers (bioluminescence spectrum)
  1 Mini-spectrometer (bioluminescence spectrum)
  2 LiDAR (alternative absorption length measurement)
  1 Muon tracker
  1 WOM (Wavelength Shifting Optical Module- JGU Mainz)

All the modules are hosted in spherical 13" high-pressure resistant glass housings.

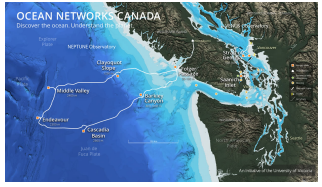
Deployment:

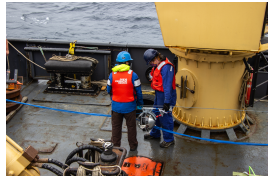
Because of the VEOCs optical fibres fragility, the chosen deployment technique followed the *top-down* approach, similar to STRAW deployment. Great complexity: the two structures that composed the string (the VEOCs and the steel cable) needed to be merged on the back deck of the ship before laying the string on the water surface.
The buoys were deployed first and dragged far from the ship by a *rigid inflatable boat* (RIB). - **ONC team**



Visual inspection:

to check if the modules showed some visible damage potentially occurred during the descent, the ROV camera performed a very close visual inspection of the entire string.





Where:

Cascadia Basin site, 2600 m b.s.l. off the shore of Vancouver Island → Ocean Networks Canada infrastructure

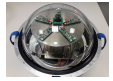
A) LiDAR: short light pulses at 450 nm of 10ns, emitted from a laser diode beam into the seawater, then scattered back and detected. The optical receiving system: a lens with a narrow-band filter for the laser wavelength focuses the light into a µPMT.
The two LiDARs host two ultra-bright, downward-pointing LEDs (broad-spectrum white LED and UV LED) to calibrate the two PMT-spectrometers placed directly below them.

B) PMT spectrometer: twelve PMTs coupled to focusing lenses and different wavelengths filters (bandpass filter from 350 to 550nm, nominal FWHM from 10 to 50nm). To take pictures of bright bioluminescence events, a compact camera has been installed at the centre of the PMT support structure.

C) Muon Tracker: aims to confirm the well-known measurements on muon flux in the deep Pacific Ocean. Two scintillator planes are coupled with optical gel to SiPMs arrays. Only time coincident signals in the two different scintillator planes are counted as muon events.

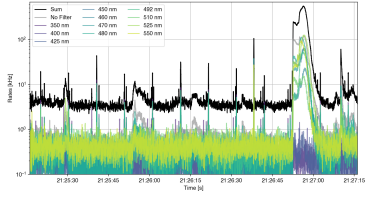
D) Mini spectrometer: complementary to the PMT spectrometer dynamic range. Composed by 5 Hamamatsu mini spectrometers (C12880MA) very compact and hermetic for high reliability against humidity. Each mini spectrometer has a high-sensitivity CMOS linear image sensor, composed of 288 pixels. The spectral range response goes from 340 to 850nm, with a spectral resolution of 15 nm.

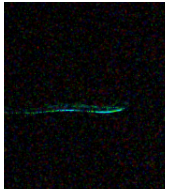
D) WOM: Wavelength shifting Optical Module-WOM (from Johannes Gutenberg - University of Mainz).



Current status:

STRAW-b modules are taking data continuously for several months, and the acquisition software is under finetuning process to guarantee stability over time. Moreover, the integration into publicly available ONC's database Oceans 2.0 (https://data.oceannetworks.ca) process is finished. Currently, the focus is on analyzing the data of the various sensors. On the right, we show the camera images and the PMT-spectrometer raw data belonging to the same bioluminescence emission event.





Scan the QR code for more info!

References:
[1] Agostini, M., Böhmer, M., Bosma, J. *et al.* The Pacific Ocean Neutrino Experiment. *Nat Astron* **4**, 913–915 (2020). https://doi.org/10.1038/s41550-020-1182-4
[2] M. Boehmer *et al.* STRAW (STRings for Absorption length in Water): pathfinder for a neutrino telescope in the deep Pacific Ocean, 2019 *JINST* **14** P02013
[3] https://www.oceannetworks.ca/