INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

Seventh Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
(IGC/IOTWS-VII)
Banda Aceh, 14-16 April 2010

Agenda Item 4.4

REPORT ON
5th MEETING OF THE INTERNATIONAL TSUNAMETER PARTNERSHIP

This document contains the report of the 5th meeting of the International Tsunameter Partnership (ITP) held in Paris, France, 26-27 September 2009. The ITP is a component of ICG/IOTWS Working Group 2 and is closely aligned with the Data Buoy Cooperation Panel (DBCP), a component of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM). The ICG is requested to consider and comment on this report.
International Tsunameter Partnership #5

RECORD OF MEETING – 26-27 Sep 2009, Paris

Meeting Chair: Mr Ken Jarrott (Australia)
Participants: See ANNEX C
Time and Place of Meeting: IOC/UNESCO Offices, Paris, 26-27 Sep 09

1. MEETING OBJECTIVES

- Review observed equipment performance for all tsunameter types – promote desirable product innovations
- Commence compilation of operational best practices
- Progress action toward consistent international exchange of tsunameter data and metadata
- Review the existing tsunameter instrument standard and guidelines
- Progress action plans with respect to vandalism and sustainability
- Inform participants of product developments
- Link the work and expertise of the ITP with that of the Data Buoy Cooperation Panel.

The ITP meeting was held immediately prior to the DBCP-25 meeting, at the same venue, to facilitate interaction between the two groups.

Given the wide ranging agenda, and the desire to engage in discussions rather than fixed-time presentations, some items received only brief attention, with follow-up deferred to the intersessional period. Refer to the Preliminary Agenda in Annex B.

2. PARTICIPANTS AND OPENING REMARKS

2.1 Participants

The Chair welcomed delegates and observers. Note was made of the representation by the People’s Republic of China at a time when China was planning tsunameter deployments, and to members of the DBCP Executive and to DBCP national and supplier representatives who were attending for the first time. The supplier fraternity was strongly represented – it included all international suppliers of moored tsunameters, one cabled tsunameter supplier, and the major governmental agencies engaged in tsunami R&D.

The Chair also welcomed the cross fertilisation from ITP national representatives and suppliers to the DBCP. He noted that several ITP national and supplier representatives had chosen to participate in the subsequent DBCP meeting. This exchange was of mutual benefit at a time when the DBCP’s mission and action agenda was also undergoing a generational change, with a new emphasis on moored ocean observatories.

Due to the staging of the meeting on the weekend, and parallel DBCP commitments, some attendees were not able to attend all ITP meeting sessions. Apologies were received from Dr Eddie Bernard (PMEL) and Mr Premkumar (Win Marine Consultancy Services).
2.2 **Opening Remarks - Sustainability**

The Chair remarked that while important work remained in the establishment of tsunameter networks, and the achievement of platform-neutral data exchange, the clear challenge arising from the collective experience of tsunameter network operators was sustainability.

Sustainability challenges included high product acquisition and ownership costs; technical and production maturity of current products; transition of products from R&D into mature long-term supply chains; and retention or transfer of expertise built up through project funding or donor contributions.

A major sustainability threat is vandalism of ocean platforms. The level of vandalism so far experienced in the Indian Ocean in particular had dramatically affected ownership costs and eroded the tsunami detection capability of warning centres.

The open exchange at this meeting between operators and suppliers and R&D agencies was seen to be vital to accelerate the availability of mature, reliable and interoperable products.

Once immediate challenges were addressed, opportunities needed to be considered for collective network optimisation and for mission value-adding, e.g. through the use of multi-role platforms, or synergistic associations with other ocean observing networks.

3. **DISCUSSION RECORD**

3.1 **DBCP Introduction**

David Meldrum (Chair, DBCP) advised that the DBCP had been formed to address circumstances in the early history of drifting buoy observations that paralleled that of today’s developing tsunameter networks. He remarked that the crisis with respect to tsunameter observations and operations had been recognized earlier that had been the case for drifting buoys.

3.2 **Current Status and Plans of National Networks**

3.2.1 **Global Network Status**

The Chair presented the status of global tsunameter networks, using Google Earth projections.
The global “sub-network” of 48 DART™ and DART-derivative products sourced from US Govt and commercial suppliers is concentrated in the Pacific Ocean, with extensions into the Caribbean and NE Atlantic, and into the Indian Ocean (through Australian, Indonesian and Thai custodians). A basin-wide maintenance mission executed by NOAA’s National Data Buoy Center is nearing completion. As a result, some 80% of the stations in the Pacific, Caribbean and NE Atlantic were currently operational.

The more heterogeneous networks of the Indian Ocean region were still impacted by network establishment activity, the transition of products from R&D, and attrition due to vandalism. Of the planned 40 stations, 24 stations had so far been deployed, fourteen had been impacted by vandalism, and only nine were reported to be functioning. Of these, none were currently distributing data internationally in real time.

3.2.2 National Reports – Australia

Network Scope and Tsunameter Types. The Australian network contains three DART™ – derivative product types: the DART II buoy, the SAIC STB and the PMEL-developed ETD – DART. The network plans are for six operational stations – two in the Indonesian arc, two in the Coral Sea and two in Tasman Sea. The network design is based on paired stations offering some redundancy in each of three distinct threat sectors, to reduce the vulnerability to single station outages. This core network will be supplemented by an experimental ETD unit in the Fiji basin. Deployment depths range from around 4,500 metres through to just under 6,000 metres.
The first buoy was deployed in the Tasman Sea in April 2007. After maintenance actions, some stations are in a “hybrid” configuration, with an SAIC surface buoy paired with a DART II bottom pressure unit, or an ETD DART surface buoy deployed over its original ocean bottom unit, but moored with a standard anchor.

Reliability and Technical Issues. Two mooring breakages have occurred. Both adrift surface buoys were recovered through ad-hoc emergency missions. The recovery missions enabled prompt reinstatement of the stations and analysis of the causes of mooring failure. A number of other product malfunctions have occurred. These have resulted in either loss of operation of the station, or performance degradation such as compromised data delivery performance.

A summary of the history of network deployment, maintenance and fault events was presented. The following failures have been experienced:

- Mooring breakaway – DART II and ETD DART
- BPR pressure data fail – two DART IIs
- BPR intermittent spiking into event mode – one DART II
- BPR recovery failure – DART II
- Vandalism – one DART II surface buoy stripped in Indian Ocean
- BPR communication failure – SAIC STB
- Glass float failures (no operational impact).

The causes have in most cases been analysed and corrected through revised manufacturing or test processes. The BPR recovery failure was not due to an ineffective acoustic release, but a failure of the released buoy to float all the way to the surface.

Australian engineering staff maintain close connections with the original product developers and with the commercial supplier (SAIC), to share learning and contribute to product improvement.

Network Operation Status vs Potential. To illustrate the gap between observed network performance and the ideal situation, a graph was presented of the number of station-reporting-days observed in any month against the number that would have been observed had all stations been fully functional. Ignoring the moderating effect of network redundancy, a network availability figure of less than 100% indicates a loss of detection capability to a warning centre. Conversely, the unplanned cost of restoring the network represents additional sustainment costs.

The Australian network had high success with its initial deployments, but network availability subsequently suffered from the failure events reported above. Since the first DART II deployment in April 07, the network’s average availability has been ~70%. At the time of the report, network availability was just over 50%, but was expected to be reinstated to better than 90% by end November, after maintenance missions were concluded.

Network failures imposed direct costs including equipment resupply and repair costs, and mission related costs, such as the costs of staff, planning, freight and vessel charter. Additional indirect costs arise from ancillary work for communications notifications, warning centre adaptations, and impact on warning capability during the station outages.

Qualifying the cost attributable to a reduction in warning capability is not straightforward, but given the high value of tsunameter information during tsunami events, it could be large.

Tsunami Measurement Performance and Data Records. A number of small tsunamis have now been observed by all three tsunameter types, including by neighbouring pairs of DART II + DART ETD, and STB + DART ETD in the Tasman Sea. All stations have demonstrated a capacity to clearly resolve very small events down to sub-centimetre wave amplitudes.

All stations report continuously via the GTS in both the original (PMEL-developed) message format and in the new CREX / BUFR coding standard developed for tsunameters. Ref [1]

High resolution event data sets are freely available, and have been supplied to PMEL.
**Sustainment Costs.** Network sustainment costs over a nine year planning period were estimated to be of the order of AUS $25M. In that context the additional operating costs arising from product unreliability or vandalism can be substantial. Of the total projected sustainment costs, the biggest single cost item (over 50% of the total) is ship costs. That is one of the reasons Australia is evaluating the new DART-ETD technology, which has the potential to reduce ship costs.

**Vessel Operations.** With only one dedicated national research vessel heavily committed and prioritised for science missions, Australia is in a different position from other nations with significant tsunameter networks. Large physical separations between tsunameters limit the capacity for optimised multi-station maintenance missions.

Australia has needed to develop flexible approach to vessel operations, with:

- **vessel-for-mission choices:** nine different vessels have so far been used for ten deployment and maintenance missions, ranging from research vessels to ocean-going tugs and fishing trawlers;
- **generic vessel charter contracts,** adapted to each mission;
- **adaptable safety processes and operational practices** that can accommodate different ships, new gear, new crew, variable mission types;
- **attention to mission leadership/crew competence** - two mission experienced crew lead missions; mission rotations of a small number of staff for resilience;
- **pursuit of tsunameter innovations that relax ship requirements** – notably the evaluation of the DART-ETD.

Australia also has established a collaborative agreement with Indonesia’s BPPT, through which Australian stations adjacent to Indonesia might be serviced using Indonesian ships.

**DISCUSSION:**

A. **Tsunameter Sustainment Costs and Cost/Benefit.** Chris Meinig (PMEL) related the cost of tsunameter development and sustainment to the costs that can be incurred when warning centres don’t have sufficient information to assess a tsunami threat. A case study in Hawaii indicated the cost of an unnecessary evacuation to be of the order of $80m. With systems aiming to prevent loss of life, cost/benefit tradeoffs are also problematic.

B. **Cause of Observed Mooring Failures.** Observed mooring failures have not been directly or solely attributed to extreme physical stress events. The DART failure was coincident with 4.5 metre seas, but it appeared that shackle failure had been a contributor. NDBC noted experience of fatigue failure of components such as shackles through repetitive cycles, not waves, due to strumming of taut moorings.

Cabled systems, while avoiding the problems of tethered surface buoys, were noted to have their own problems. Deployment and recovery operations are a challenge, with use of underwater vehicles, deck space, and position keeping being critical. Electrolysis problems needed to be guarded against.

C. **DART – ETD Operational Certification.** Bill Burnett (NDBC) asked on what basis an ETD would be qualified as operationally ready. Ken Jarrott responded that the ETD was being treated as a “new” product that required qualification, but in practice, the cost of exhaustive new product testing in this domain was prohibitive, so risk/benefit judgments needed to be applied. The ETD had been subjected to a physical and functional test regime by PMEL during its development. It has proven its measurement consistency against DART II or SAIC STB inter-comparison stations. An ETD has delivered data to the Australian warning system for over 18 months, and has performed successfully during two tsunami events. While these tests do not fully eliminate risks or fully qualify the ETD performance envelope, the ETD qualification regime exceeds that of many new products in this arena. Further joint Australian - Indonesian ETD trials are planned in 2010.
3.2.3 National Reports – India

Network Scope and Tsunameter Types. India reported its history of competitive trial of three tsunameter products, leading to the choice of its current solution, which combines Sonardyne’s ocean bottom unit with an Indian-developed surface buoy and INMARSAT satellite communication. The stations are typically deployed at 3,000 metres depth, with the surface acoustic transponder at 15-20 metres beneath the surface buoy. India was investigating the purchase of an established DART™-based system, which provided an end-to-end solution, for inter-comparison with its own tsunameters.

Network Status. At the time of the meeting no Indian surface buoys were operating. The network had experienced a high incidence of vandalism. Surface buoys were removed from both stations deployed in the Arabian Sea.

Reliability and Technical Issues. Data from tsunami events had been recorded and relayed live to the Indian Tsunami Warning Centre, but data transmission problems had also been experienced. Many of the losses are attributed to the surface buoy, with vandalism and communications link failures. Isolating the cause of data losses to the underwater communications link, to buoy movement during high sea states, to the buoy watch circle, or the interface between the surface data acquisition system and satellite communications is not straightforward. India was examining each of these. The loss of underwater signals due to the surface buoy watch circle and to buoy pitching in high sea states was thought to be one factor. A redundant modem link on the surface buoy was being considered. India also proposed measurements of sea surface wind and rainfall to identify any correlation with satellite link dropouts.

A 10% failure rate had been experienced in retrievals of ocean bottom units.

Solar cells were attractive items to equipment thieves, so the NIOT-developed surface buoy is being re-engineered with battery power, to avoid the use of solar cells. The Indian network would not be re-seeded until this new solution was ready.

Vessel Operations. NIOT uses purpose-built ocean research vessels, which also service an existing Indian moored buoy network. Thirty deployment operations and 23 retrieval operations had so far been conducted across its 12-buoy network.

Tsunami Measurement Performance and Data Records. The Indian tsunameter network had recorded both tsunami events and seismic disturbances, and agreed to contribute high resolution data from these events. Data from the four stations that recorded the 12 Sep 2007 Sumatra tsunami event would be passed to PMEL as a global collection point. Data that could be retrieved from ocean bottom units that were still recording would also be made available. India plans to make real time data available on the GTS through the endorsed data formats.
DISCUSSION

**Battery Power Sources.** With India’s move to battery power sources, there was discussion on reliable battery suppliers for Alkaline and Lithium battery power packs, and issues around the air transport of Lithium batteries. With the high energy demands of communication systems, India saw that high energy density was important for its surface buoy design. Chris Meinig (PMEL) advised the need to secure a certified battery pack. Sonardyne indicated their use of Lithium batteries for the ocean bottom unit, which had a conservative 600 days of energy capacity and an ability to self-detect a low battery and to switch to a low energy operation.

3.2.4 National Reports – Indonesia

**Network Scope and Tsunameter Types.** The Indonesian component of the combined Indonesian-German tsunameter network was initially planned to be ten stations, but this has been reduced to eight, in part due to a high incidence of vandalism, with four stations so far affected. Apart from Indonesian-developed buoys (InaBuoys), there are plans to deploy two DART-ETD stations. One, in cooperation with NOAA, will be to the south of Sumatra, and another, for joint trial under the collaborative agreement with Australia, will be to the south of Bali.

The InaBuoy had undergone surface buoy hull redesign since the first trial units. Technical issues experienced included a high background noise in the bottom pressure record, failure of Benthos glass floats, and corrosion inside the Paroscientific pressure transducer module.

Indonesia is considering the suitability of cabled tsunameter technology within its network.

**Vessel Operations.** Indonesia (BPPT) has access to four ships, but ship accessibility has suffered through demands for unscheduled maintenance missions.

**Tsunameter Measurement Performance and Data Records.** Data was recorded by the Indonesian-developed InaBuoy during the 12 Sept 2007 Sumatra event, and that data set will be provided to PMEL for compilation with other nations’ records from the same event. Other stations (e.g. the US donated DART buoy, which had been subject to surface buoy theft) had recorded events, and data would be uploaded from functioning bottom pressure recorders where possible.

Indonesia wishes to share real time tsunameter data through standard formats, and to utilise the broader range of data available through the data buoy fraternity. With the community of scientific staff working with such data in Indonesia still being relatively small, a training workshop on ocean data exchange was proposed to accelerate progress on this. The ICG /IOTWS 7 meeting in April, and the IOC/WESTPAC Meeting in Bali in May identified as possible opportunities.
3.2.5 National Reports – Germany / GITEWS

Network Scope and Tsunameter Types. The German Indonesian Tsunami Early Warning System (GITEWS) plans for a network of 10 deep ocean tsunami monitoring stations, deployed in waters up to 6,000 metres deep. The systems will use a combination of GPS measurement technology on the surface buoy, and pressure and seismic sensors on the ocean bottom unit. In the combined pressure / seismic bottom units the bottom pressure sensor is a glass sphere containing all the equipment (payload, battery). The GITEWS surface buoys are large (6 metre diameter). The acoustic modem is located 10 metres below the surface.

Network Status. Eight buoys have been deployed. Seven stations are currently in place. All but one of the current systems use GPS technology, and only one is equipped with a bottom pressure sensor. The intention is to stabilise on a common standard, once data communications from ocean bottom units with combined seismic and pressure sensors are resolved. Broadband underwater acoustic communications capable of transmitting sea level (pressure) data and the more extensive data from seismic sensors are still under development.

![Map of GITEWS network](image)

Reliability and Technical Issues. Apart from technical developments still in progress, the stations have been subject to vandalism events, and to mooring breakages. Some of the vandalism events included mooring line cutting and damage through fishing line fouling, antenna and solar cell damage through ship contact, and tower structures lost through impact with ships. GITEWS recommends an International decree to stop vandalism.

The challenge to address for Indonesia is the proximity of the tsunamigenic sources, and systems that function appropriately for more distant tsunami threats in other ocean basins find limitations in the Indonesian context. For closely threatened communities there is a special challenge to estimate the time of arrival of tsunamis more than the height of the wave, so the lower resolution of the GPS stations is less critical.

The goal in Indonesia is to put out alerts/warnings in 10 mins based on as many tsunami observations as can be obtained.

Vessel Operations. A large German research vessel is used to deploy the stations.

Tsunameter Measurement Performance and Data Records. GPS position is being sampled at 1Hz. Filtering is used to discriminate tsunami waves from normal sea surface motions and tides. The current resolution for tsunami waves is 10 cm. An example was presented of an event on 2 Sept 2009, measured tsunami from one GPS buoy.
3.2.6 National Reports – Malaysia

Network Scope and Tsunameter Types. Malaysia plans a network of three stations. Two have been deployed - one near Rondo, and one at Layang-Layang Island. A third is planned for the Sulu Sea, near the Philippines. All stations are supplied by Fugro Oceanor, and use the Wavescan surface buoy. They are deployed in relatively shallow waters, at depths of under 500m. The stations also measure waves and met information (wind, current, temperature). Data is transmitted from the surface buoy by INMARSAT, and is relayed to Malaysia via Norway.

Network Status and Technical Issues. The Rondo buoy has been in place since Dec 05, and the Layang station since March 06. The deployment of the third station awaits the signing of an agreement between Malaysia and the Philippines. It is expected to occur soon. The systems have experienced a number of technical problems. Buoy 1 operated for three months and had noise issues. Buoy 2 operated for a few months before failure. Failure of transmission was believed to be caused by the batteries on the ocean bottom unit. The battery capacity has since been doubled, but another failure has since occurred. Multiple failures have been experienced with the surface buoy, and corrosion has been found in the ocean bottom unit. Malaysia had one surface buoy drift from its station, but it was recovered. There are no reported incidents of vandalism.

Vessel Operations. Malaysia does not have a ship so they depend on Indonesia for ship support. Stations are serviced twice a year.

3.2.7 National Reports – USA

Network Scope and Tsunameter Types. NOAA has established 39 DART™ stations contributing to PTWS Caribbean and NE Atlantic tsunami warning capabilities.

Network Status. At 25 September, with a major maintenance mission still underway (see below), approximately 80% (31 of the 39 stations) had reported in the last 48 hours.
There are multiple inter-agency contributions in the USA to the tsunameter network operation, performance analysis, and data management and interpretation. They include:

- **PMEL**: station siting recommendation; BPR data QC analysis, including trend analysis and comparison with research; forecast modelling and DART data inversion
- **National Data Buoy Center**: buoy deployment, recovery and maintenance; real time quality check of incoming data messages; display and distribution of BPR data; metadata collection and distribution; retrospective high resolution data recovery
- **Center for Operational Oceanographic Products and Services**: tidal analysis of BPR data to refine and maintain tidal harmonic constants
- **National Geophysical Data Center**: detiding and tidal prediction; metadata organisation and archiving; event data archiving and distribution
- **Tsunami Warning Centers**: DART interrogation; system testing; issue of warnings.

**Reliability and Technical Issues.** A number of “technical” and physical (mooring) failures have occurred. In the years 2006-2008, there were 14 instances of surface buoys going adrift. Two were not recovered, one was confirmed to be due to wear, and three had their mooring lines cut. The others are due to unknown causes, but it is likely that some were due to vandalism. Mooring analyses are being performed to reduce mooring failures.

The following technical problems were also reported:

- occasional (15 cases) of date sticking in standard mode reporting - corrected
- false events, including spiking of pressure readings in the BPR, noted also noted in the Australian network, and persistent level shifts, possibly due to settling of the BPR
- abnormal drift of the Paroscientific pressure sensor, due to a vacuum leak of the reference cell – dessicant fill is recommended.

NDBC is applying automated tools to analyse and detect anomalies and to improve component tracking for reliability studies and life cycle analysis. A DART Quality Control Group will meet for the first time in the US in November.

An “Extended Mode Variable Schedule” enhancement was to be incorporated to enable the BPR which had already been triggered into event mode reporting by a seismic disturbance to be re-triggered into high frequency reporting, so as to capture an arriving wave.
**Tsunami Measurement Performance and Data Records.** The US has an extensive set of event records and high resolution data sets recovered from BPRs. Near-real-time data is available on the GTS in the PMEL protocol, via the NDBC’s web site [http://www.ndbc.noaa.gov/dart.shtml](http://www.ndbc.noaa.gov/dart.shtml) and through DODS/OpeNDAP protocol in NetCDF format via the url: [http://dods.ndbc.noaa.gov/thredds/catalog/data/dart/catalog.html](http://dods.ndbc.noaa.gov/thredds/catalog/data/dart/catalog.html).

**Sustainment Costs.** An annual network maintenance cost of ~US$10m was indicated, of which a little over half was attributed to vessel operations.

**Vessel Operations.** A major seven month trans-Pacific maintenance mission using the vessel *Ocean Pioneer* is nearing completion. The mission duration is 194 at-sea days, and 207 days in total. The total mission length is ~66,000km, with six planned crew swaps.

**DISCUSSION:**

**Causes of Station Failure.** Dr Rajendran (India) requested an analysis of the causes of station failure experienced in the US network, and a breakdown into mooring (physical) failures and failures attributed to BPRs and surface buoys. Bill Burnett offered to provide such a breakdown.

**3.3 Supplier Briefings**

### 3.3.1 Sonardyne (UK): Nick Street

Sonardyne had supplied 20 ocean bottom units to India’s National Institute of Ocean Technology. Elements of the technology were based on standard ocean survey transponders. The ocean bottom unit uses a Paroscientific “Digiquartz” pressure sensor, an acoustic data link (high speed 1 kb/s, forward error correction, wideband), and a Lithium battery pack.

Sonardyne has also observed some anomalies with step changes in pressure sensor output after a long period of operation, and they were working with Paroscientific on that. Problems have been experienced with flotation collars, for which there are no test facilities. These have been apparently random supply problems. Implosions were witnessed in some tests. One failure of the acoustic release has also been experienced, despite the success of the release operation being reported by the bottom unit. Physical entanglement in cables was a possible cause.

A new design of the surface unit acoustic transceiver had been undertaken.

Sonardyne ocean bottom units had recorded a number of events. Four stations recorded the Sumatra event of 12 September 2007, and records of the seismic disturbance of the Magnitude 6.2 Nicobar Islands earthquake of 25 Jul 2007. Some of the records received by the tsunami warning centre have data gaps, but it was not clear where the data dropouts occurred.

Nick described the present generation of Sonardyne’s Autonomous Monitoring Transponder and for ocean floor monitoring applications, and advised of the developments of a next generation unit with dual pressure sensors and a compact Lithium battery pack delivering 4-5 years of operating life.

### 3.3.2 Lighthouse R&D (USA): Justin Simcho

Lighthouse have installed a prototype cabled underwater observation system for Oman. It is deployed in the Gulf of Oman, and operates at a depth of 1300 metres. It was jointly developed with the Woods Hole Oceanographic Institution (USA).

The Seismic Tsunami Early Warning System (STEWS) combines a broadband seismometer with pressure sensors measuring water column height and current meters. It has a nominal four-year maintenance cycle. The system is complex and expensive to install, requiring high value and not commonly available vessels and Remotely Operated Vehicles for deployment and maintenance. It
also requires a companion on-shore facility providing power, data receipt and communications functions. In suitable locations, the higher install costs are justified by the greater data collection capability and bandwidth, an extended operating life of the cable and on-shore infrastructure, and lower annual operating costs. The system is also not susceptible to the problem of surface buoy vandalism.

Technical issues experienced with the prototype system include corrosion / electrolysis of ocean floor couplings, and continuity of utility power for the remotely located shore station. These are being addressed.

Lighthouse is working with the government in Oman to provide free and open access to the data, with the understanding that the system is a prototype. High volumes of data arrive at Lighthouse offices in Houston within seconds. They are looking for help to analyse the data.

Data sets have been obtained for seismic events originating in the Makran subduction zone, and will be provided to PMEL for analysis. Lighthouse is looking to automated Quality control of observations data, and are discussing this with Woods Hole.

Discussions are underway with other Indian Ocean countries whose situation may suit the use of cabled systems.

### 3.3.3 SAIC (USA): Rob Lawson

As the engineering support contractor to the National Data Buoy Center, SAIC has built over 50 DART™ units. Its San Diego facility has developed the STB variant, incorporating some engineering changes and using a modified surface buoy with an ionomer foam hull.

SAIC is currently under contract for supply of systems to Australia and China. A number of its systems are in operation in the Australian network, either in a full STB station configuration, or in some cases with an STB surface buoy paired with an existing DART™ ocean floor unit. SAIC’s initial STB trial unit recorded tsunamis raising from the Kuril Islands earthquake in 15 Nov 2006. An Australian STB station in the Tasman Sea recorded an earthquake and small tsunami event in July 2009. The event record closely matched that of a co-located ETD-DART inter-comparison station.

SAIC is planning to build and deploy ETD systems. It has entered into a licensing agreement with NOAA to facilitate this. They expect the first SAIC-built ETD system to be in the water early in 2010.

### 3.3.4 Envirtech S.p.A. (Italy): Daniel Calore

Envirtech is involved in design and development of instrumented monitoring for meteorological and oceanographic observations. It has supplied 17 buoys for the wave monitoring network around Italy, and is engaged in tide monitoring around Venice.

Envirtech has built two generations of tsunami monitoring buoys. Initial units were supplied to India for tsunami meter product trials in 2007. The new models, which are currently being supplied to China, have incorporated several engineering changes. They can be fitted with optional sensors, including surface met sensors, a wave measurement pack, current meters and ocean floor seismometers. Surface units are powered with Lithium batteries, and have an 18 month operating life. The underwater acoustic link supports 5kbits / sec transmission up to full ocean depth. The tsunami detection algorithm is a modified form of the Mojfield algorithm, incorporating a neural network algorithm with a 20 day learning period to improve tide prediction error.

Two of the first generation Envirtech systems were deployed by India (NIOT) in the Bay of Bengal. They recorded data from the Sumatra earthquake and tsunami of 12 Sep 2007. High resolution data from this event will be made available to PMEL, for assimilation with other data sets from that event.

Envirtech are under contract to supply two systems to China, for use in the South China Sea.
3.3.5 **NOAA Pacific Marine Environmental Laboratory: Chris Meinig**

The report focussed on the developments of the Easy-To-Deploy variant of the DART™ system (ETD—DART), with extension to anti-vandalism experiments.

PMEL has been involved in the ETD development for some years as an offshoot of its work on a ocean observing platform with low ownership cost. It was pursuing ETD development to the point of a mature, demonstrable concept.

ETDs use tsunami detection and reporting technologies derived from prior generations of DART product, but with a physical form that dramatically simplifies deployment operations, and reduces logistics costs and dependencies on high value. ETD surface buoys have provision for met sensors.

ETDs have now been deployed in high and low latitudes, and had been deployed by both the US and Australia. They have recorded tsunami events in situations where a nearby DART II had provided an inter-comparison reference. The ETD had met or exceeded requirements agreed with the US Tsunami Warning Centres.

ETD endurance testing was continuing. The Hawaii location had been used for 2.5 years, and the North Pacific site for 2 years. Data availability was reported at 92% in the N Pacific, and 94% in Hawaii. Australia had operated an ETD station in southern latitudes for over 18 months. Chris remarked that system development required persistence and was not without peril. ETD developments so far have involved 16 deep-water deployments, and 20 shallow-water anchor and shock tests. Two systems were lost in 2006 and one in 2008.

The concept of a disposable ETD ocean bottom unit attracted discussion in recent scientific conferences, about the impact of not being able to recover the full record of high resolution data. There was a cost trade-off between system life cycle costs and while-of-life data access, and the current design delivers the lowest ownership cost for the ETD’s primary mission. High resolution data for any tsunami event is available during an event and can be remotely downloaded after the event. The cost of access to whole-of-life high resolution data sets is very high.

One of the refinements being investigated by PMEL is the fabrication of multi-purpose mooring line, able to incorporate heterogeneous line segments into a repeatable, buildable process. The intention was to transfer the anchor line and ETD mooring / spool capability to industry.

Chris reported an anti-vandalism adaptation to an Indian Ocean buoy. Ocean moorings in that region had suffered very short lifetimes due to vandalism, and few data sets extended beyond a period of months. A conical cap was retro-fitted over an existing surface buoy hull to remove access to exposed structures or masts, and to deny boarding opportunity and points of vessel attachment. While this required the removal of surface sensors and towers, the modified buoy has so far delivered a continuous time series of SST, SSS, subsurface temperature and salinity for one year, telemetered via Argos. Subject to the continued success of this prototype mooring, new vandal resistant surface sensors could be reintroduced.

3.4 **SPECIAL TOPICS**

3.4.1 **Near-Source Tsunamis (A Tasman Sea Example): Ken Jarrott**

A small tsunami generated off the south of New Zealand on 15 Jul 09 was recorded by two co-located tsunameters in the Australian network – a DART II and an ETD DART. The stations were close to the source and vigorous seismic ringing was still present at the time of wave arrival, visually contaminating the wave signature. In areas presented with near-source threats, and where tsunameters have no choice of a more distant placement at a seismically quiet location, this circumstance will be common.

The event provided an opportunity to look at practical means to assist a warning centre to estimate wave parameters in real time. The presence of two co-located stations was valuable for
this analysis – the underlying wave was near-identical at both locations, so the comparison of analyses from both buoys should reveal the “truth”. The received waveforms reported by the two tsunameters were visually different. Aliased 1-minute averaged seismic disturbance showed as differently phased disturbances at the two stations, visually reinforcing or subtracting from the first wave peak.

Spectral analysis of high resolution data from both stations was of no value – it revealed the expected heavy aliasing of high frequency seismic disturbance, smearing energy across all energy bands, including the band containing the dominant tsunami wave energy. So frequency analysis of received data doesn’t help. Complex digital filters operating over number of samples helped reveal the tsunami wave by attenuating the higher frequency seismic contaminants, but filter processing lags would have contributed significant delays to a decision process.

Ultimately, very simple filtering using a running 2 minute average, combined with a simple spike removal step, revealed a clear and near-identical wave representation from the records of both stations. This unsophisticated approach quickly revealed wave amplitudes.

The experience suggests that a very simple “real-time image clean-up” tool might be very useful for warning centres presented with this circumstance. Full analysis of high-resolution 15 second data is still required after the event, but during an event, when decision time is important, a simple set of tools might quickly reveal the nature of the tsunami. As with commonly used photographic image clean up software, being able to apply and rapidly visualise the results from different a set of filter parameters via a “slider” control might also be valuable. Warning centre staff can get some confidence in the appropriate amount of filtering, by seeing tsunami waveforms first emerge from attenuated background noise, and then themselves get attenuated by filtering that is too aggressive.

Australia intends to test the utility of this technique on other event records.

3.4.2 Australian Tsunameter Performance: Ken Jarrott

Despite interruptions in continuous station records due to technical failures, mooring breakages or vandalism, Australia’s experience of a modest-sized tsunameter network was sufficient to point to the underlying potential of the technology, and to prospective future operating performance and costs. In summary:

- **Physical Conditions.** Stations are deployed from 3,300m depth through to 5,700m. All are in relatively low current areas. The Tasman Sea stations experience high winds and sea conditions (14 metre waves observed on one occasion.). Northern stations are exposed to tropical cyclones (no direct cyclone hits yet).

  Mooring line load sensors on the ETD units have not recorded loads approaching the mooring design limits, even under extreme sea conditions.

- **Station Longevity.**
  - The Tasman Sea 1 DART II system had 12 months continuous operating from initial deployment, with solid data returns, before a routine surface buoy change-out. The BPR operated for 2 years before a planned maintenance change-out.
  - The Coral Sea 1 – surface buoy had 18 months of continuous operations before a routine maintenance change-out.
  - The Tasman Sea 2 (ETD) station had eight months continuous operations with good data returns in a tough environment before a mooring break. The BPR unit has been operating continuously for 18 months.
  - The surface buoy of the SAIC-supplied Tasman Sea STB station has so far provided six months of continuous operations with good data returns.
• **Measurement Chain Performance.** Three small tsunamis had so far been observed, including by closely paired Tasman Sea stations (a DART II –ETD pairing, and an SAIC STB+ETD pairing). These events revealed a capacity for consistent and clean discrimination of small tsunami signals, down to sub-centimetre amplitude.

• **Data Delivery Performance.** Analysis of a recent month of data returns of the Tasman Sea SAIC STB showed a data return success of >99% for both primary and secondary channels (i.e. successful receipt of messages on either the first, second or third attempt).

The ETD DART exhibited solid data returns during its initial eight months of service, but since its re-establishment with a different mooring scope and an extended watch circle, primary channel data returns for background transmissions have been degraded (76%). The degradation is attributable to higher losses in the underwater link due to the watch circle extension. Even with degraded background mode data delivery, the ETD has reported reliably in event mode, due to the smaller event-mode message blocks.

Australia’s operational experience to date reveals the potential of the underlying technology and design of the DART II and its more recent variants, the SAIC STB and the ETD-DART. It supports confidence in the realisation of design targets for measurement performance, station life and data delivery performance in the near future, as corrective response to observed equipment failures improve underlying product reliability.

3.4.3 **The Problem of Near Field Tsunami Prediction: Joern Lauterjung**

For near-field sources, the tsunami observation and forecast problem is different from the forecast of tsunamis originating at a great distance. For a far-field tsunami, the generating source may be treated approximately as a point source, and observation stations may be placed sufficiently far from the source for the seismic “noise” signal to have dissipated before the arrival of the tsunami. In extreme cases of a near-field tsunami, the travel distance to affected communities may be comparable to the rupture length of the source.

Current tsunameter designs use a bottom pressure sensor to discriminate the change in ocean column pressure, which could arise from the seismically-induced movement of the ocean floor or the passage of a tsunami. In a near-field tsunami forecast zone, this presents a problem. The tsunami wave disturbance needs to be extracted in the presence of a coincident seismic disturbance which is both energetic and poorly sampled due to the pressure sensor response time.

Joern proposed that forecasting for locations close to rupture zones in Indonesia would be improved by a dense network of close-to-source stations able to capture the time of arrival of a disturbance, so as to identify the rupture direction of the source. While far field forecasts may not be materially affected by this knowledge, local impacts may vary considerably.

**DISCUSSION**

Use of a high bandwidth seismic sensor (accelerometer) in the ocean bottom system could provide independent measurement of ocean floor movements, and enable those to be subtracted.

A pressure sensor mounted with a float above the ocean floor may help decouple the seismic signal from the tsunami signal, but this could cause other problems. Chris Meinig advised that Paroscientific was developing a higher frequency response, but it would also use more power.

Indonesia was considering the use of two pressure sensors, one in the ocean bottom unit and one in the mooring line – to be able to segregate the seismic and tsunami disturbances. Vertical movements of the mooring line present difficulties for this approach.

Joern Lauterjung proposed a workshop on the near field tsunami warning problem. This was agreed as a very worthwhile action.
3.4.4 Data Exchange
The ITP-initiated BUFR/CREX templates for GTS transmission of tsunameter sea level data are adopted and will appear in the operational WMO Manual on Codes after 15 Sep 2010. Ref [1] Australia has been transmitting data in the new BUFR code form for pre-operational trial since March 2009. For an interim period, it is also transmitting tsunameter data on the GTS using the original PMEL format.

NDBC is providing all their tsunameter data on their website and the GTS, using the NOAA-PMEL legacy format. NDBC should be providing their data in the new BUFR code format soon, but global GTS dissemination will be by 2012. NDBC is providing their DART data on the OPeNDAP website and the Standard Data Format (SDF). An RSS feed has also been established. Other countries are still only transmitting tsunameter data to national warning centres.

3.4.5 DBCP and ITP Association
A proposal to affiliate the ITP with the DBCP was discussed. The synergies with the DBCP were clear, and recognized by members of both groups. The potential benefits of the DBCP’s experience base and technical support services to the ITP’s current work plan and long-term evolution were also recognized. Reciprocally, the ITP would bring to the DBCP a new data buoy application, new ocean platform technologies, new national and supplier participants that complements the DBCP’s current initiatives in moored buoys, including the OceanSITES program. The challenge of vandalism and more generally the sustainability of moored ocean platforms was a common challenge for the two groups.

While the technical association between the ITP and DBCP was a natural one, the ITP’s current governance structure and accountability through the ICG/IOTWS requires attention in any transition. For the immediate future, the ITP’s contribution to the development and maturation of the IOTWS in particular needed to be a clear focus, irrespective of broader global engagement with the DBCP and with other global tsunami warning systems. A revised governance arrangement needed to attend to both regional and global responsibilities.

Discussion among ITP national representatives and suppliers indicated concern that the current focus of the ITP might be dissipated, with participants potentially needing to choose between attending an ITP meeting (currently regionally based) or the annual DBCP meeting.

4. NEXT MEETING
The next ITP meeting to be notified at least six months in advance. Date / venue to be discussed out of session.

5. REFERENCES
[1] CREX / BUFR Template for Transmission of Sea Level Data from Tsunameters Refer WMO International Codes web page http://www.wmo.int/pages/prog/www/WMOCodes.html Volume I.2 will bring you to the web page of Operational Codes, Pre-operational entries and Amendments to be incorporated in the Manual on Codes. The BUFRCREX templates for tsunami data is under "Amendments to be incorporated in the Manual on Codes".

NOTE: printing error in one of the Table B entries for the DART buoy templates. The reference value for 022184 should be -2000, not 2000.
<table>
<thead>
<tr>
<th>Ref</th>
<th>Action</th>
<th>Person Responsible</th>
<th>Action By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tsunameter Network Status Updates</td>
<td>Germany - Lauterjung, Indonesia - Hartoyo</td>
<td>2 Oct '09</td>
</tr>
<tr>
<td></td>
<td>1.1 Complete round of national updates to tsunameter network status</td>
<td>K Jarrott</td>
<td>30 Apr 2010 or next survey</td>
</tr>
<tr>
<td></td>
<td>1.2 Incorporate China, Oman stations in future status surveys and map projections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>IOTWS Tsunameter Vandalism Record Update</td>
<td>Germany (GITEWS) - Hartoyo</td>
<td>2 Oct 09</td>
</tr>
<tr>
<td>3</td>
<td>Trial of New CREX / BUFR Data Transmission by Non-DART Platforms</td>
<td>Trials by India, Germany, Fugro</td>
<td>Feb 2010</td>
</tr>
<tr>
<td></td>
<td>At least three countries / tsunameter suppliers are to trial the coding of native tsunameter data transmissions into forms that comply with the new CREX / BUFR standard. The trials are to demonstrate file encoding or decoding, and are to precede trials of international data transmissions. Decoding trials can use the real-time Australian tsunameter transmissions as a source.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Data Exchange (General)</td>
<td>All tsunami network operators</td>
<td>On-going, accountable at next ITP meet</td>
</tr>
<tr>
<td>5</td>
<td>Sustainability</td>
<td>K Jarrott</td>
<td>Oct 09</td>
</tr>
<tr>
<td></td>
<td>(Continuing action from prior meeting). Draft paper on the sustainability challenge to be prepared.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.1 Oman STEWS Cabled System – Seismic Event Record</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.2 SAIC – 1 Year of High Res STB Trial Station Data, incl Kuril Is Event</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.3 India – All stations records 12 Sep 2007 Sumatra Event</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.4 Indonesia – 12 Sep 2007 Sumatra Event</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.5 Indonesia – Event Data from DART ETD and US-Donated DART</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.6 Envirtech – data from seismic event, trial station, Bay of Bengal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>DBCP Integration</td>
<td>K Jarrott</td>
<td>DBCP Paris meet Sep 09</td>
</tr>
<tr>
<td></td>
<td>7.1 Convey ITP interest in a practical affiliation with DBCP</td>
<td></td>
<td>May 2010</td>
</tr>
<tr>
<td></td>
<td>7.2 Solicit feedback from ITP members on practical issues of DBCP integration, explore means of ITP access to DBCP technical support, develop position paper.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Best Practice Framework</td>
<td>Australia &amp; U.S.</td>
<td>before next ITP meet</td>
</tr>
<tr>
<td></td>
<td>Propose a Best Practice Framework for the ITP group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Workshop on Near-Field Tsunami Warning Problem</td>
<td>J. Lauterjung and others</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>Develop proposition for a workshop on the near-field tsunami warning problem, possibly in conjunction with the next ITP.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Breakdown Failure Analysis – US Networks</td>
<td>B. Burnett</td>
<td>Feb 2010</td>
</tr>
<tr>
<td></td>
<td>Provide NIOT (Dr Rajendran) with a breakdown of known causes of failure attributed to surface buoys, BPRs and moorings in the NDBC-operated DART networks.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Effective ITP Website (on-going action)</td>
<td>Chair and others, in consult. with IOC</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>Establish effective web site for publication and exchange of information between ITP participants.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Preliminary Agenda
International Tsunameter Partnership Meeting
26-27 September 2009
UNESCO / Miollis Building, Paris

(Note: Final agenda to be framed in accord with the quality of materials circulated prior to the meeting, the availability of key participants, and the most effective use of meeting time.)

Saturday 26 Sep 0900hrs – 1700 hrs

0900: Registration
09:30: Meeting Start

AGENDA ITEMS

- Introduction and Review of Agenda
- Review of Actions from Prior Meetings
- Status and Plans for National and Regional Networks
  - Aggregation of nationally-prepared network status reports for the Indian Ocean, Pacific Ocean, Caribbean and North Atlantic regions, with discussion. Contributory reports to be submitted prior to meeting.
  - Consideration of plans for new station deployments (operational or trial).
- Review of Collective Tsunameter Performance Experience
  National operator or supplier analysis of key tsunameter functions or system components, for each type of tsunameter, including:
  - Measurement chain performance – resolution, noise, drift attributes
    - Tsunami event analyses and data sets
    - Performance of GPS buoys
  - Data communications – underwater and surface (satellite) data delivery performance for background and event mode reporting. Impact of adverse conditions on data delivery performance. After-receipt (eg internet) data distribution channels.
  - Power sub-systems - technologies and energy budgets
  - Mooring systems – robustness, stress factors, taut vs slack-line mooring designs and experiences
  - Physical / environmental housings
- Lessons Learned from Observed Failures or Problems
  - Review of problems experienced, causal analysis and corrective actions across all basins and all product types, with a view to learning or insights applicable to others
- Review of Operational or Network Management Practices
  - Shared lessons and experiences from ship deployment or recovery missions
ANNEX B - AGENDA

- Life cycle support planning, including station visitation regimes, maintenance findings. Operating cost profiles and key drivers.
- Station and network monitoring techniques and network-operator management processes
- Network renewal or maintenance planning, including product or technology transition plans
- Key drivers of operating costs

Sunday 27 Sep 0900hrs – 1700 hrs

- Event Analysis by Warning Centres Using Tsunameter Data
  - Case studies of recent events using live (during-event) data or off-line analyses of retrieved data. Engagement models between tsunameter operators / data providers and warning centre functions.
  - The challenge of near-source tsunameters. Wave discrimination in the presence of seismic noise.
- Product, Technology or Process Developments
  - Developments by suppliers or R&D agencies
  - Current results of Australian – US evaluation of Easy-to-Deploy DART
- Tsunameter Standards and Guidelines
  - Review of existing standard
  - Test and operational acceptance processes
  - Incorporation of guidelines for new product qualification
- International Data Exchange
  - International data exchange protocols and work plans
  - Metadata requirements and solution options
- Sustainability
  - Sustainability issues and responses – global and regional
  - Vandalism – scope, consequences, and strategies
- Communications Principles and Aids
  - Achieving an effective collaboration and communication among ITP participants
- Harmonisation of ITP and DBCP Work Plans, Expertise and Modes of Operation
  - DBCP terms of reference and operating model
  - DBCP and ITP interaction issues and progress steps
  - ITP relationships with regional Tsunami Warning Systems
- Review of Actions and Recommendations
  - (including issues to present to the DBCP meeting)
PARTICIPANTS LIST

NOTE: Not all participants were able to attend all meeting sessions.

<table>
<thead>
<tr>
<th>Name and Designation</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AUSTRALIA</strong></td>
<td></td>
</tr>
<tr>
<td>Ken Jarrott, Chair ITP</td>
<td>Head, Business Process and Projects Section Observations and Engineering Branch Australian Bureau of Meteorology GPO Box 1289 Melbourne VIC 3001 Australia Tel: + 61 3 9669 4163</td>
</tr>
<tr>
<td><strong>CHINA</strong></td>
<td></td>
</tr>
<tr>
<td>Dr Chun Lin Ning</td>
<td>Lab. Ocean-Atmosphere Interaction and Climate Change First Institute of Oceanography China Tel: +86 532 88960702</td>
</tr>
<tr>
<td><strong>GERMANY</strong></td>
<td></td>
</tr>
<tr>
<td>Dr Joern Lauterjung</td>
<td>Physicist Geoforschungs Zentrum Potsdam D-14473 Potsdam Germany Tel: +49(0)3312881020</td>
</tr>
<tr>
<td><strong>INDIA</strong></td>
<td></td>
</tr>
<tr>
<td>Dr V Rajendran</td>
<td>Group Head, National Data Buoy Programme NATIONAL INSTITUE OF OCEAN TECHNOLOGY, Velachery - Tambaram Main Road Naraynapuram, Pallikaranai Chennai 600 100 Tamil Nadu India Tel: +91 44-22462039</td>
</tr>
<tr>
<td><strong>INDONESIA</strong></td>
<td></td>
</tr>
<tr>
<td>Ridwan Djamaluddin</td>
<td>Agency for the Assessment &amp; Application of Technology (BPPT) BPPT 1st Bld, 18th floor, JLN. MH Thamrin 8 Jakarta 10340 Indonesia Tel: +62-21-3168800</td>
</tr>
<tr>
<td>Dr Wahyu Pandoe</td>
<td>Head of Program Division Agency for the Assessment &amp; Application of Technology (BPPT) BPPT 1st Bld, 18th floor, JLN. MH Thamrin 8 Jakarta 10340 Indonesia Tel: +62-21-3168813</td>
</tr>
<tr>
<td>Dr Michael Purwoadi</td>
<td>Director MEPPo-BPPT Agency for the Assessment &amp; Application of Technology (BPPT) BPPT Bldg II, 11th floor, JLN. MH Thamrin 8 Jakarta 10340 Indonesia Tel: +62-21-3169363</td>
</tr>
<tr>
<td><strong>MALAYSIA</strong></td>
<td></td>
</tr>
<tr>
<td>Mohd Rosaidi Che Abas</td>
<td>Director, Geophysics &amp; Tsunami Division Malaysian Meteorological Department Jalan Sultan 46667 Petaling Jaya Selangor Malaysia Tel: 603-79678000</td>
</tr>
<tr>
<td><strong>SRI LANKA [OBSERVER]</strong></td>
<td></td>
</tr>
<tr>
<td>Dr Sam Hettiarachchi</td>
<td>Chair, ICG./ IOTWS Working Group 3 (Risk Assessment) Professor Moratuwa Sri Lanka</td>
</tr>
</tbody>
</table>
### USA

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/Role</th>
<th>Organization</th>
<th>Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christian Meinig</td>
<td>Leader, Engineering Development</td>
<td>NOAA Pacific Marine Environmental Laboratory</td>
<td>7600 Sand Point Way NE Seattle WA 98115 United States Tel: +1 206 526 6149</td>
<td></td>
</tr>
<tr>
<td>Dr William Burnett</td>
<td>Branch Chief</td>
<td>NOAA National Data Buoy Center</td>
<td>1100 Balch Blvd. Stennis Space Center MS 39529 United States Tel: +1 228 688 4766</td>
<td></td>
</tr>
</tbody>
</table>

### IOC/UNESCO

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/Role</th>
<th>Organization</th>
<th>Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Koltermann</td>
<td>Head of Section</td>
<td>Intergovernmental Oceanographic Commission of UNESCO</td>
<td>1 rue Miollis 75732 Paris cedex 15 France</td>
<td>+33 145684015</td>
</tr>
<tr>
<td></td>
<td>IOC Tsunami Unit</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DATA BUOY COOPERATION PANEL

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/Role</th>
<th>Organization</th>
<th>Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Meldrum</td>
<td>DBCP Chair</td>
<td>Leader of Technology Development</td>
<td>Scottish Association for Marine Science Dunstaffnage Marine Laboratory Dunbeg Oban, Scotland PA37 1QA United Kingdom Tel: +44 1631 559 273</td>
<td></td>
</tr>
<tr>
<td>Al Wallace</td>
<td>DBCP Vice Chair – North America</td>
<td>Director, Weather and Environmental Operations</td>
<td>Environment Canada 201-401 Burrard Street VANCOUVER V6C 3S5 BC Canada Tel: +1 604 664 9090</td>
<td></td>
</tr>
<tr>
<td>Hester Viola</td>
<td>DBCP Technical Coordinator</td>
<td>JCOMM in situ Observing Platform Support Centre (JCOMMOPS)</td>
<td>8-10, rue Hermes Parc Technologique du Canal 31526 Ramonville Saint-Agne CEDEX France</td>
<td>+33 561394782</td>
</tr>
</tbody>
</table>

### SUPPLIERS

**FUGRO OCEANOR, Norway**

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/Role</th>
<th>Organization</th>
<th>Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Schjolberg</td>
<td>Project Manager</td>
<td>Fugro Oceanor AS</td>
<td>Pir-senteret, N-7462 Trondheim, NORWAY</td>
<td>+47 73545221</td>
</tr>
</tbody>
</table>

**LIGHTHOUSE R&D Enterprises, USA**

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/Role</th>
<th>Organization</th>
<th>Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justin Simcho</td>
<td>Global Sales</td>
<td>Lighthouse R&amp;D enterprises, Inc.</td>
<td>16945 Northchase Drive ste 100 Houston TX 77060 United States Tel: 281-447-4100</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Position</td>
<td>Company</td>
<td>Address</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------</td>
<td>----------------------------------</td>
<td>----------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Ken du Vall</td>
<td>President, COO</td>
<td>Lighthouse R&amp;D enterprises, Inc.</td>
<td>16945 Northchase Drive ste 100</td>
<td>Houston TX 77060</td>
</tr>
<tr>
<td>Jeffrey Snider</td>
<td>Marketing Director</td>
<td>Lighthouse R &amp; D Enterprises, Inc.</td>
<td>16945 Northchase Drive Suite 100</td>
<td>Houston TX 77060</td>
</tr>
<tr>
<td>Nick Street</td>
<td>Engineering Team Leader</td>
<td>Sonardyne International Ltd.</td>
<td>Blackbushe Business Park Yateley Hampshire GU46 6GD</td>
<td></td>
</tr>
<tr>
<td>Rob Lawson</td>
<td>Vice President, Director International Tsunami Buoy Program</td>
<td>SAIC</td>
<td>4065 Hancock Street, San Diego, CA 92110, USA</td>
<td></td>
</tr>
<tr>
<td>Dr Daniele Calore</td>
<td>Project Manager</td>
<td>Envirtech S.p.A.</td>
<td>16121 Genova 37, Via XX Settembre Italy</td>
<td></td>
</tr>
<tr>
<td>Mark Blaseckie</td>
<td>Technical Field Services</td>
<td>AXYS Technologies Inc.</td>
<td>2045 Mills Road West Sidney V8L 5X2 BC Canada</td>
<td></td>
</tr>
</tbody>
</table>