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IEEE OCEANIC ENGINEERING SOCIETY

EX-OFFICIO

ELECTED ADMINISTRATIVE COMMITTEE

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President's Corner

As the second year of my term begins there is much excitement on the horizon. The Society has an ambitious schedule for this year. We will continue with two major conferences. The first is in Singapore in May and the second is in Boston in September. In addition, several symposia are also on the agenda. Our second journey to Klaipeda, Lithuania is scheduled for the latter part of May and as of this writing we have over 130 papers and a distinguished set of plenary speakers from US and Europe. Our biennial AUV workshop will be held in Brest, France the site of our successful OCEANS 05 conference. Our participation in the IEEE effort for GEOSS is ramping up as the project is now in the design stage. There will be a series of workshops relative to the GEOSS run by a group of IEEE Societies in cities around the Globe. This is in addition to our normal society functions so it is obvious that it will be a busy year. So once again I would like to put out a call for some volunteers to lighten the load. Many hands make each task a lot lighter.

During the past year your Society officers and volunteers have accomplished the following list of tasks:

Design, development and implementation of a package of web based tools that assist conference organizers in the planning and implementation of our OCEANS conferences. They can also are available for symposia /workshops in a reduced format. They include automated handling of abstracts, web page backbone for OCEANS, and a start on a registration tool. Many thanks go to Todd Morrison for his efforts on this task.

Continuation of the Society involvement in several student related programs either financially or with volunteer help or both. These include the National Ocean Science Bowl run by CORE, the International Submarine Races run by FURE with OES assistance and MATE an ROV competition backed by MTS. Norm Miller has been carrying our flag for NOSB. Claude Brancart has been our lead for the ISR and Jim Barbera has been the POC for MATE.

Our constitution and bylaws were reviewed and rewritten this past year by a group of "ten" led by Jim Collins. This is a time consuming task and all are to be congratulated. As you know the constitution was voted on and approve in the summer. Some of the macro changes are as noted here. The Treasurer and Secretary are now elected vice appointed positions, a VP was added for Conference Operations, and the JOE editor is now a member of the executive committee.

Collaborated in the formation of a group known as ICEO to

pursue IEEE involvement in the worldwide Global Earth Observation System of Systems. Through the efforts of this group the IEEE has been named as a co-chair on the Architecture and Data committee. In addition, Sandy Williams is on the team that is examining a worldwide Tsunami warning system.

Planned and ran two major OCEANS conferences, one in Brest, France in June and the other in Washington D.C in September. Both conferences were very successful. The Current Measurement technology committee had their workshop in Southampton, England. The Homeland Security committee held a workshop in Newport, Rhode Island that was well attended. This committee also went to Moscow and Gdansk to attend homeland events in those cities. Bob Bannon and Jim Barbera were the society representatives.

I am sure I missed something so please forgive me in advance for any oversight as it was not intentional.

Every year at this time a new class of AdCom members come aboard. As you remember you voted for these candidates in the fall. Therefore, I am pleased to welcome aboard the following new AdCom

Rene Garello	Region 8
Mal Heron	Region 10
Milica Stojanovic	Region 1
John Watson	Region 8
Fred Maltz	Region 6
Bob Wernli	Region 6

I am looking forward to another exciting year. A final thought- if every member would recruit one member this year the Society would double in size and there would be more volunteers to assist with our programs. See you in Singapore and Boston.

Jim Barbera, IEEE/OES President

René Garello, VP Conference Operations

In early 2001, Tom Wiener, then president of the OES, asked me to head a committee to formalize our conference activities, finding the proper balance between the responsibility of the sponsoring society and the authority and autonomy of the local organizing committee, and improving the management of our conferences so that our technical, professional, and financial goals are met.

I named this committee, CoCoPo (Committee on Conference Policies) and this was the real start of my greater involvement with the operations of the OCEANS conferences. This committee came up, among other things, with the two conference-a-year concept, the first edition of which I chaired in Brest in June 2005. In the meantime CoCoPo evolved into JOAB (cf. the paper "From CoCoPo to JOAB: A new era in Oceans Conferences" in a previous issue of the Newsletters) which implemented the tools necessary for insuring a sustainable procedure for the OCEANS conferences and to support the coming "future" ones. In the last four to five years CoCoPo and JOAB have achieved a great part of the challenge proposed by Tom Wiener. There has been an evolution from a first concept – advisors revolving around a paid consultant – to another approach, more internal to the societies: a Web exchange between the local organizing committees, the advisors and the data.

Parallel to that, OES rejuvenated the Constitution & Bylaws of the society and separated the position of VP international into two vice-presidencies: development and operation of the conferences. I had the feeling that my experience with CoCoPo, JOAB and running a conference (Oceans'05 Brest) made me fit for the job. I was really pleased to be elected to this position in September last year. I have since then, as VP Conference Operations, worked towards a greater reinforcement of the link between the local organizing committees and the society resources. The main challenge consists first of coordinating the help we, society, can provide to all the new conferences coming up: technical domain, website tools and more generally all pertinent advices (Exhibit, .Tutorials, Student Program, etc.). I just had a look at my agenda and here is the program for the next conference which are already granted and for which support is starting: Oceans'06 Singapore, Oceans'06 Boston, Oceans'07 Aberdeen, Oceans'07 Vancouver and I'm not counting two or three more which have already started early and are waiting (Oceans'08 Quebec, Oceans'09 Bremen …).

By the time I'm writing these lines we are still at the very beginning of 2006, so I wish the best to all the OES members and their family.

Homeland Security Technology Workshop December 6-8, 2005 – Newport, RI

by Robert Bannon and Pam Hurst, IEEE OES AdCom

The IEEE – Oceanic Engineering Society (IEEE-OES) and NAVSEA-Naval Undersea Warfare Center (NUWC) co-hosted the third IEEE-OES Homeland Security Technology Workshop - Ocean and Maritime Technologies for Infrastructure Protection at the Marriott Hotel and Resort , Newport, RI on December 6, 7, and 8, 2005. As with the past workshops, the theme was "Under the Water, On the Water, and Over the Water" for the Protection of the Homeland. The purpose of the workshop was to bring together small technology companies, and large defense contractors, military, government, academia, and not-for-profit institutes who are developing technologies and products for Ocean and Maritime Technologies for Infrastructure Protection This IEEE-OES workshop provides an unprecedented opportunity to network with engineers, scientists, maritime legal experts, and local, state, and federal government personnel who all share a common concern and goal in providing advance technologies to protect vital maritime infrastructure and provide for the safety of our ports, harbors, coastal eco-systems and our oceans.

Pam Hurst, HSTW Chair, opening the Conference and welcoming the Attendees to the Marriott

Pamela Hurst, Bob Bannon, IEEE Fellow, and Jim Pollock, NAVSEA NUWC returned as the Conference Chair and Co-Chairs respectively. Unfortunately, legislative duties in Washington, D.C. prevented the Honorable Curt Weldon, U.S. House of Representatives – R-PA 7th District, from participating as a keynote speaker this year. However, Congressman Weldon wrote a letter of introduction for Bob Bannon who was this year's banquet speaker.

Bob stated that Homeland Security has become a global issue not only in the United States, the UK, Italy and The Russian Federation, but has become a major focus in the Ukraine, Turkey, Malaysia and Poland.

The Russian Federation is now participating in international collaboration to fight terrorism:

- Organized by the CIS Antiterrorism Center, the CIS Collective Security Treaty Organization, Ministry of Foreign Affairs of the Russian Federation, Ministry of Internal Affairs of the Russian Federation and Federal Security Service of the Russian Federation.

Bob Bannon presenting a global view of Homeland Security

- Urgent Issues of Counteraction to Modern Terrorist Threats
- Criminology and Crime Detection Systems in Prevention and Investigation of Acts of Terrorism
- Video Surveillance Guard Systems in Prevention of Terrorism Threats - Department of Protection of Public Property, Research Center at the Ministry of Internal Affairs of the Russian Federation
- Systems and Means of Communications in War against Terrorism - Directorate of Information Telecommunication Technologies and Communications of the Department of Rear Services and Organizations at the Ministry of Internal Affairs of the Russian Federation.

Hong Kong is set to lose its title as world's busiest container port to Singapore this year and Shanghai and Shenzhen ports are steadily catching up in volume. Hong Kong moved 21.93 million 20-foot equivalent units (TEUs) of goods last year, up 7.3 per cent from the year earlier. Singapore, the world's second-busiest port, handled a record 21.3 million TEUs in 2004, up about 16 per cent due to booming regional trade, according to port operators.

Vulnerable submarine cable nodes exist on both sides of the Atlantic. For historical and technical reasons most trans-Atlantic cables terminate in the SW of the UK and NE of the

Sam Roudebush and Shawn James – Maritime Domain Awareness Panel Leaders

USA. These nodes are vulnerable because the cables are protected only from "normal" seabed activities and because most seabed users diligently avoid cables. However, a particularly "aggressive" trawler could damage most trans-Atlantic cables in a few days or hours. New threats are emerging resulting from terrorist activities.

At the conference another item discussed was the need to fix support systems for our First Responders – FEMA, USCG, and Local Police and Fire Departments. In addition, we need to encourage and pursue development of inter-agency communications devices and provide delivery networks for essential supplies.

USCG RDML Joseph Nimmich addressed Maritime Domain Awareness issues and the challenges that the Coast Guard face after 911 in protecting U.S. coastal waters, ports and harbors and critical maritime infrastructure. This was followed by a USCG Panel chaired by Sam Roudebush, Sonalysts, Inc. and Shawn James, VP Integrated Domain Awareness & Security at Lockheed Martin Co.

Jim Pollock, NAVSEA NUWC Director of Homeland Security Programs and Pam Lisiewicz NUWC Associate Director for Planning and Technical Operations chaired a Government Perspective Panel on Homeland Defense Initiatives.

Senator Lincoln Chafee, R-RI, addressed the HSTW05 attendees at lunch on Thursday on the history Rhode Island has played in U.S. naval history and the protection of maritime infrastructure.

The technical program offered two full days, featuring 6 multi-track PowerPoint presentations and papers covering topics below:

- Underwater Telecommunications Protection Issues and International Legislation
- Sensors and Underwater Vehicle Technology for Protecting our Ports, Waterways, and Coastlines
- Preempting and Disrupting Terrorist Threat
- Maritime Domain Awareness
- Biometric and Screening – including Personnel and Containers
- Unmanned Underwater Vehicles (UUVs) for Hull and Pier Inspections
- Explosive Ordnance Acquisition and Disposal
- Technologies for Countering Chemical, Bio-terrorist, Terrorist Attacks on Ocean Industries
- Anti-Swimmer Technologies
- Beyond Homeland Defense and Homeland Security – Over the Horizon

The workshop was successful because it focused creative resources, collective energy and commitment on protecting vital ocean and maritime infrastructure on a global scale.

Acknowledgements: Photographs courtesy of Stan Chamberlain, OES VP- Technical Activities."Nuclear Car Wash" information - D. Slaughter, M. Accatino, A. Bernstein, et al, p 560, Sensors Journal Aug, 2005.

RDML Joe Nimmich, USCG, explaining the Coast Guard role in U.S. asset protection

Bob Bannon, Jim Pollock, Sen. Lincoln Chafee and Pam Hurst

Request for Nominations to the Administrative Committee, Class of 2007

The IEEE Oceanic Engineering Society is governed by an Administrative Committee is 18 members. Six are elected each year to serve three-year terms. Members are limited to two consecutive terms, although they may be reelected after a lapse of one year.

The Nomination and Appointments Committee is Chaired by the Junior Past President, with the Senior Past President and the most recently retired Senior Past President completing the Committee. We are charged with proposing a slate of nominees and with conducting the election, which is done by mail to the entire membership.

Qualifications for Administrative Committee membership are membership in the IEEE and OES, and a willingness to serve the oceanic engineering profession. We wish to have the Administrative Committee characteristics reflect characteristics of the IEEE membership. We are particularly interested in increasing the Asian and European membership of the Committee.

I ask that each of you identify and nominate qualified candidates for the Administrative Committee. Self-nomination is encouraged.

The Nomination Packet should include a Letter of Nomination accompanied by a one page biographical sketch of the proposed candidate and a one-page statement from the proposed candidate giving his or her views of the opportunities and challenges facing the Society and steps to be taken to advance the IEEE Oceanographic Engineering Society.

The election will be conducted in accordance with the new Bylaws adopted last year that came into force on January 1, 2006. You can read them by going to the Society's Web Site (www.oceanicengineering.org), and pointing to Bylaws 2006 under Governing Documents. The Bylaws specify that general nominations close on March 1, and nominations by petition close by April 15.

Please submit nominations to the undersigned.

Please do not delay your efforts in finding and nominating qualified candidates.

Thomas Freud Wiener, Sc.D., LSMIEEE
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Request for Nominations for the IEEE Oceanic Engineering Society Distinguished Service Award for 2006

The IEEE Oceanic Engineering Society is seeking nominations from Oceanic Engineering Society membership for the Oceanic Engineering Society Distinguished Service Award for 2006.

The Distinguished Service Award is presented to the Oceanic Engineering Society member who has distinguished herself or himself in her or his service to the Oceanic Engineering Society and the profession. The last five Distinguished Service Awardees are:

The Nominations Packet(s) for the Oceanic Engineering Society Distinguished Service Award should include a Letter of Nomination accompanied by a one page vita of the candidate. Nominations will be accepted through 15 April 2006.

Please submit nominations to the undersigned.

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Upcoming Conferences

February 8-10, 2006
Scientific Submarine Cable 2006
Dublin, Ireland
www.ssc06.com

February 28 -March 2, 2006
China Maritime Exhibition 2006
Hong Kong
www.baird.com.au

March 6-10, 2006
World Maritime Technology Conference 2006
London, England
www.wmtc2006.com

March 21-23, 2006
Oceanology International 2006
London, England
www.oi06.com

May 1-4, 2006
Offshore Technology Conference 2006
Houston, Texas
www.otc-net.org

May 16-19, 2006
Oceans 2006 Asia Pacific IEEE Conference
Singapore
www.oceans06asiapacific.org

May 23-25, 2006
U.S. /European Union Baltic International Conference 2006
Klaipeda, Lithuania
www.us-baltic2006.org

June 21-23, 2006
Energy Ocean 2006
San Diego, California
www.energyocean.com

September 18-22, 2006
Oceans 2006 MTS/IEEE
Boston, Massachusetts
www.oceans2006.org

Pair-wise Processing of Spectrograms for Localization of Multiple Broadband CW Sources

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Abstract—**A pair-wise processing algorithm has been developed to localize broadband sources in shallow water. A simple sparse hydrophone array with number of elements roughly equal to the maximum number of sources is used. The sources can be continuous-wave (i.e. no onset times), and no previous knowledge of source signatures is required. The processor is spatially coherent and partially frequency coherent. Simulations show considerable improvement over conventional (i.e. frequency incoherent) matched field techniques under realistic noise conditions, with environmental mismatch and multiple sources. Spectrograms have been incorporated into the algorithm to make use of higher frequencies at greater ranges. Our work is motivated by the problem of localizing multiple singing humpback whales.**

I. INTRODUCTION

The goal of our research is to extend and implement passive acoustic localization algorithms for use in tracking vocalizing humpback whales on winter breeding grounds. Acoustical techniques have advantages over visual and tagging techniques since they are non-invasive and unobtrusive, they are not interrupted by poor weather conditions or lack of daylight, they enable continuous and remote sensing, and they are cost and time efficient.

Although localization methods for underwater sources have made great progress over the last 25 years (see [1]-[3] for overviews), their application to humpback whale localization is problematic because of their need for large numbers of hydrophones, e.g. vertical line arrays, assets that are seldom available to scientists studying whales. Accordingly, acoustical methods for locating whales have often relied on simple assumptions, such as constant sound-speeds and straight-line propagation, that are not satisfied by the shallow water environments in which humpbacks are usually found [4]. Model-based methods (i.e. those that use computer models of acoustic propagation) are desirable in this problem, but available model-based methods can be difficult to apply, mainly due to the characteristics of humpback vocalizations. These include:

- Unknown waveforms: the whale's song is not known (or, technically, how far the whale is into the song is unknown).
- Continuous waveforms: song units typically consist of up-sweeps, down-sweeps, and constant-frequency contours [5].
- Multiple sources: singers tend to space themselves about 4-6 km apart [6], although the spacing becomes tighter with increasing density of whales.
- Broadband, mid-frequencies: 30 Hz – 8kHz [7].

Since model-based algorithms depend on the agreement of measured signals with synthetic signals, they have difficulty with high-frequency sources, i.e. sources located many wavelengths from receivers. For source-receiver offsets many wavelengths long, fluctuations and uncertainties in sound speed profile and bathymetry distort actual signals to the point where they no longer agree with signals synthesized under the assumption of a constant environment. Thus popular model-based techniques have been limited to low frequencies (well below 1 kHz) where such environmental mismatch is less harmful. Only recently have mid and high frequencies started being explored for use in source localization [2], [8].

Another limit to existing techniques is that most require additional assumptions about the source. For example it is often assumed that there is only one source, or that the source waveform is known, impulsive, or narrow-band. In addition, as noted above, some techniques rely on line arrays. We consider arrays with a few hydrophones separated by many source wavelengths (sparse arrays) because they are often the only type of array available to whale researchers, and they are usually the simplest and least

costly type of array [9]. Various sparse arrays currently in operation (e.g. AUTEC, PMRF, and the Southern California Offshore Acoustic Range) can be used to gather marine mammal data.

In this work we address the problem of low spatial resolution (of arrays with relatively few hydrophones) by utilizing the frequency coherence of the source signal as well as its spatial coherence; we do this without the usual requirement that the source signal be known. We address the problem of lowered coherence at high frequencies by processing spectrograms instead of waveforms.

II. ALGORITHMS

To deal with unknown, continuous-wave sources, a pair-wise waveform (PWW) processor is used. It is an extension of the pair-wise inversion technique of Frazer and Sun [10], with application of ideas from Westwood's broadband processor [11]. Here we assume that all hydrophones have the same unknown transfer function; arrays in which different hydrophones have different transfer functions can be accommodated by four-wise processors [10] with lower resolution.

To understand the PWW processor, consider the received signals at two hydrophones, $R_1(\omega)$ and $R_2(\omega)$. Let $\hat{G}_1(\omega)$ and $\hat{G}_2(\omega)$ denote the channel Green's functions from the source to the first and second hydrophones, respectively. The received spectra (measured) are the products of the source spectrum, $W(\omega)$, with the impulse responses, i.e.

$$R_n(\omega) = W(\omega)\hat{G}_n(\omega) \qquad n = 1, 2.$$

Now, let $G_n(\bar{x},\omega)$ denote the modeled Green's functions between receiver *n* and candidate source location $\bar{x}$. We introduce the following two products:

$$H_{12}(\bar{x},\omega) = R_1(\omega)G_2(\bar{x},\omega)$$
$$H_{21}(\bar{x},\omega) = R_2(\omega)G_1(\bar{x},\omega).$$

Denote the correct source location by $\bar{s}$. Then $G_n(\bar{s},\omega) \approx \hat{G}_n(\omega)$ (approximately since the propagation model cannot be perfect). This leads to:

$$H_{12}(\bar{s},\omega) \approx W(\omega)\hat{G}_1(\omega)\hat{G}_2(\omega) \approx H_{21}(\bar{s},\omega).$$

For a single pair of receivers our PWW processor (a probabilistic indicator of source location) is given by

$$\varphi(\bar{x}) = \frac{\sum_{\omega}\left[\left(H_{12}\right)^* H_{21} + \left(H_{21}\right)^* H_{12}\right]}{\sum_{\omega}\left|H_{12}\right|^2 + \sum_{\omega}\left|H_{21}\right|^2} \qquad (1)$$

where * denotes conjugation. The reason for this definition of $\varphi(\bar{x})$ can be understood as follows. Think of H_{12} and H_{21} as two complex column vectors with frequency as the row index. Concatenate them twice, once with H_{12} above H_{21}, then vice-versa, to make two longer vectors. Then $\varphi(\bar{x})$ is just the normalized inner product of these two longer vectors. The definition above is preferable to just taking the inner product between H_{12} and H_{12} directly because it adds symmetry to the algorithm; it does not matter which receiver is named 1 and which is named 2. By the Cauchy-Schwartz inequality, the processor reaches its maximum value (unity) when $H_{12} = H_{12}$. In particular, $\varphi(\bar{x})$ is maximized at the true source location $\bar{x} = \bar{s}$.

To reduce computational requirements, note that ${H_{21}}^* H_{21} = \left({H_{12}}^* H_{21}\right)^*$. Consequently, the PWW processor can be written as:

$$\varphi(\bar{x}) = \frac{2\,\mathrm{Re}\left(\sum_{\omega}{H_{12}}^* H_{21}\right)}{\sum_{\omega}\left|H_{12}\right|^2 + \sum_{\omega}\left|H_{21}\right|^2} \qquad (2)$$

The single-pair PWW processor can be generalized to $N > 2$ receivers by summing coherently over receiver pairs:

$$\varphi_{pww}(\bar{x}) = \frac{2\,\mathrm{Re}\left(\sum_{\omega}\sum_{i=1}^{N-1}\sum_{j>i}^{N}{H_{ij}}^* H_{ji}\right)}{\sum_{\omega}\sum_{i=1}^{N}\sum_{j\neq i}^{N}\left|H_{ij}\right|^2}. \qquad (3)$$

To address the problem of incoherence at long ranges, we process spectrograms instead of waveforms. We call this the pair-wise spectrogram (PWS) processor. Spectrograms are less sensitive to mismatch and fluctuations in the ocean wave-guide, particularly at higher frequencies. Our use of spectrograms is in the spirit of envelope processing [2] in which signal envelopes are processed instead of waveforms. In contrast to envelope processing, however, PWS processing retains both time and frequency characteristics, and can still benefit from coherence at low frequencies.

Let $S_{ij}(\bar{x},t,f)$ denote the spectrogram formed from $H_{ij}(\bar{x},\omega)$, where *t* and *f* are time and frequency steps respectively. Above the crossover frequency *fc* (to be determined), only the envelope of each channel is processed,

and the mean is removed from each envelope because a constant offset holds no information. The formula for the PWS processor is analogous to that of the PWW processor:

$$\varphi_{pws}(\bar{x}) = \frac{2\,\mathrm{Re}\left(\sum_t \sum_f \sum_{i=1}^{N-1} \sum_{j>i}^{N} S_{ij}{}^{*} S_{ji} \right)}{\sum_t \sum_f \sum_{i=1}^{N} \sum_{j\neq i}^{N} \left| S_{ij} \right|^2} \qquad (4)$$

Once again, intuition into this processor is gained by thinking of the spectrograms as vectors and taking normalized inner products. Of course, a weighting over frequencies and/or times may be introduced in either of the processors above to emphasize or de-emphasize certain aspects of the signal. For a slowly drifting source, for example, it may be advantageous to put more weight on more recent times.

V. SIMULATION SPECIFICS

The Bartlett, PWW, and PWS processors were implemented in MATLAB [12]. Bellhop [13] was used to model impulse responses. Simulations were run for a 700 m by 700 m by 200 m (constant depth) area. The sound speed profile used was typical of that seen in Hawaiian winter waters. It was based on historical values taken from the Generalized Digital Environmental Model [14]. A humpback whale signal, 40 s long and sampled at 2 kHz, was propagated (by convolution with modeled impulse responses) from several source locations to several receiver locations within the range. A spectrogram of the signal used is shown in Figure [1].

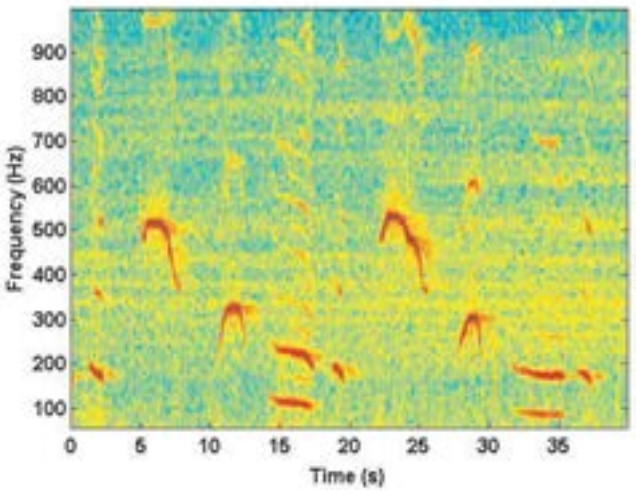

Fig. 1. Spectrogram of humpback whale signal used in simulations.

Simulations shown here are for a case with 1 source and three receiver, and another case with two sources and four receivers. Figures [2] and [3] show the source/receiver layouts as well as the search areas from a top down perspective. In the first case the source was at (252 m, 304 m, 60 m) and the three receivers were at (47 m, 102 m, 60 m), (175 m, 647 m, 60 m), and (603 m, 200 m, 60 m). In the 2 source case, the first source and three receivers were in the same positions as in the 1 source case. The second source was at (452 m, 573 m, 60 m) and the fourth receiver was at (677 m, 697 m, 60 m). The same signal was used for the second source as for the first source, with the first 20 s and the last 20 s swapped in the time domain.

Simulated noise was of the worst-case type: many noises sources with source signatures identical to that of the actual source, except for their randomized strengths and start times. These "noise whales" were placed at every grid point in the search area. The signals from the "noise whales" were propagated to the receivers and summed in time to give the background noise. The power of the "noise whales" was adjusted to give a specified average signal-to-noise ratio (SNR) over all receivers.

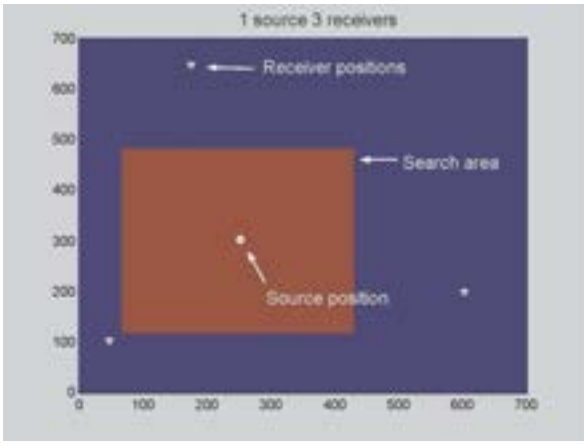

Fig. 2. Simulation layout for 1 source simulation. Vertical and horizontal distances are in m.

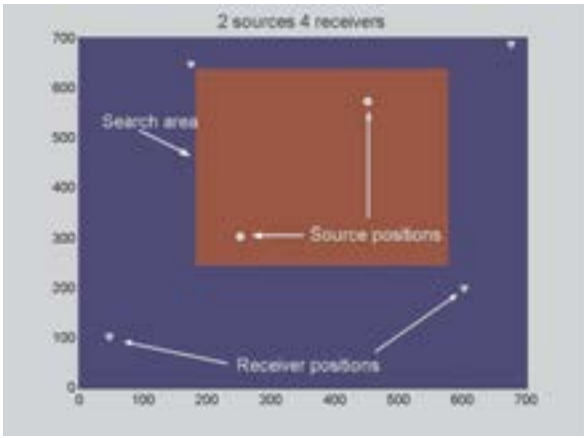

Fig. 3. Simulation layout for 2 source simulation. Vertical and horizontal distances are in m.

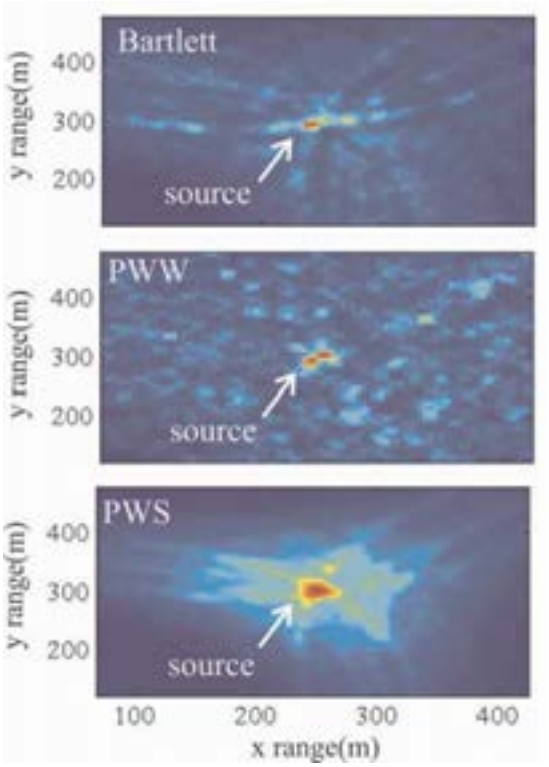

Fig. 4. SNR 5 dB. 1 source, 3 receivers. All three processors successfully localize the source

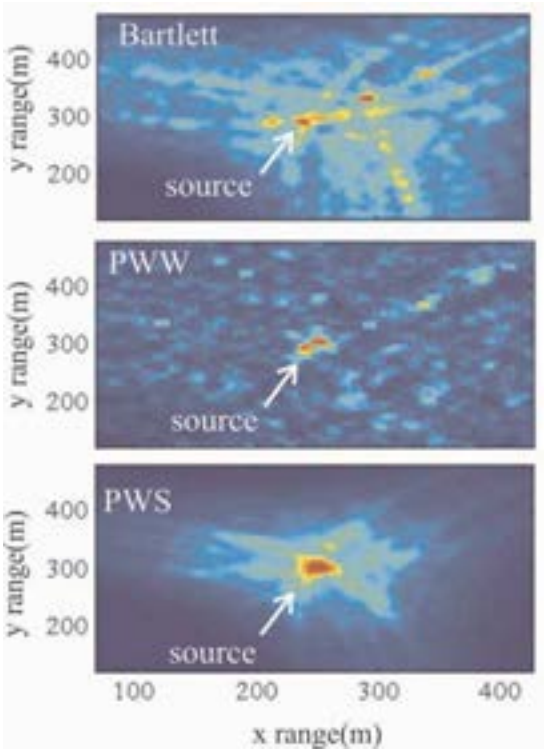

Fig. 5. SNR 0 dB. 1 source, 3 receivers. The PWW and PWS processors successfully localize the source which is lost to the Bartlett processor.

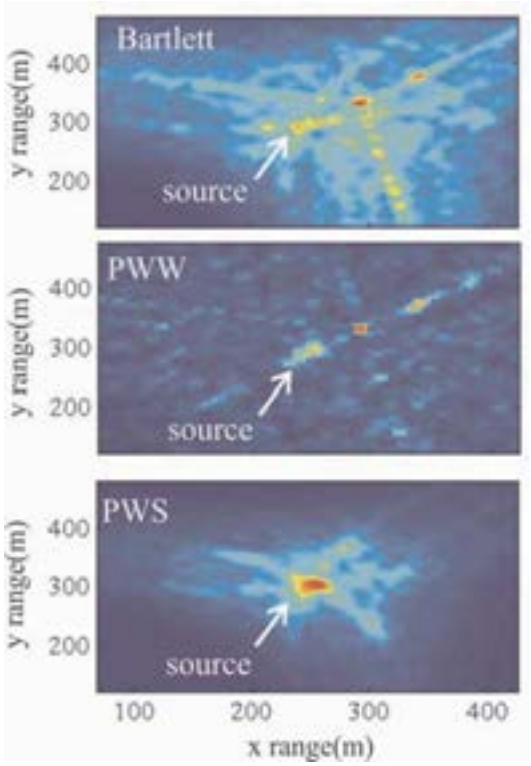

Fig. 6. SNR -5 dB. 1 source, 3 receivers. Only the PWS processor successfully localizes the source.

After generation of the noisy, synthetic data, the PWW, PWS, and Bartlett algorithms were used to try to locate the whales. The grid used in the localization was at a single depth (60 m) and grid spacing was 4 m (ultimately, searches will be conducted over several depths). Spectrograms were generated using a 256 point FFT. Signals were Hanning windowed prior to computing each spectrum, and there was a 128 point overlap between successive time windows of the spectrogram. Environmental mismatch was introduced in the form of incorrect water depth; all inversions shown are for a depth of 204 m rather than of 200 m. SNRs were gradually decreased to explore the localization error due to noise. Only frequencies up to 200 Hz were used in the Bartlett and PWW processors since higher frequencies became too incoherent to add useful information. For the PWS processor, the crossover frequency *fc* was 100 Hz .

VI. DISCUSSION

Ambiguity surfaces for the three processors for increasing levels of noise are shown in Figures [4]-[6]. The images have been individually scaled so that red and blue correspond to the maximum and minimum surface values, respectively. At 5 dB SNR, all three processors localize the source accurately. At 0 dB SNR, however, spurious sources begin to appear with the Bartlett processor, while the pair-wise processors still find the source. Increasing the noise to -

5 dB, only the PWS processor correctly localizes the source. Only the PWS processor is able to localize both sources in the 2 source case with 0 dB SNR (Fig. [7]).

It is evident from these simulations that the PWS is more robust with respect to noise and mismatch than the other two processors, but that this benefit is gained by loss of resolution. Indeed, the localized sources in the PWS surface are "smeared" over a larger area. This effect is minimized by raising the cutoff frequency, *fc*, and/or by reducing the number of points in the spectrogram FFT window.

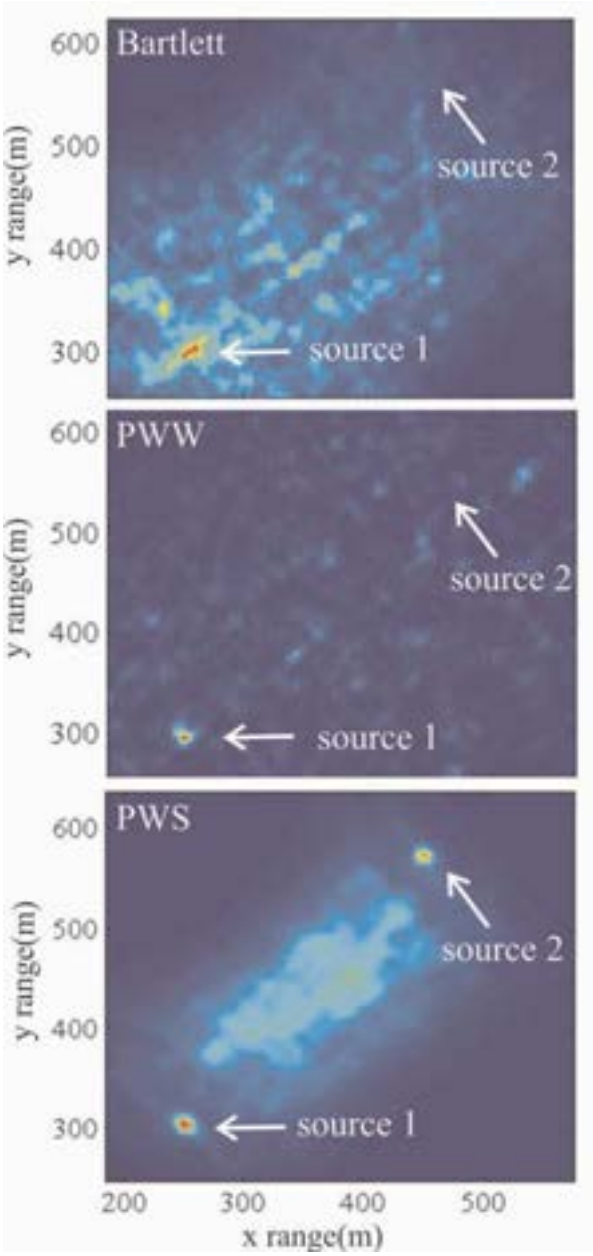

Fig. 7. SNR 0 dB. 2 sources, 4 receivers. Only the PWS processor localizes both sources (4 receivers).

VII. CONCLUSION

A pair-wise spectrogram (PWS) processor has been proposed for the localization of multiple broad-band unknown continuous-wave sources in shallow water. It appears robust with respect to mismatch and noise; with only three receivers, a single source could be localized under conditions of both environmental mismatch and signal to noise ratios worse than –5 dB. Two identical (but unknown) sources could be localized in mismatch and 0 dB SNR. Many aspects of these processors remain to be explored though simulations and analysis of real data.

Of interest for future work is the use of cochleagrams instead of spectrograms in the PWS processor. These are auditory representations of sound (as heard by whales) whereby a cochlear filter-bank [15], [16] is applied to the signal. Being biologically more relevant than spectrogram processing, cochleagrams may prove to aid in localization – perhaps the whales know something we don't.

Currently, efforts are being made to modify the PWS processor to further reduce computational requirements, which will allow us to work at longer ranges and at higher sampling frequencies.

ACKNOWLEDGMENT

This project is currently funded by the Maui High Performance Computing Center (MHPCC) and by ONR. E.-M. N. is grateful for the support of scholarship from the Natural Science and Engineering Research Council of Canada. Thanks to MHPCC and to G. Ito and G. Moore of the University of Hawaii for computing resources.

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Eva-Marie Nosal was born in Calgary, Alberta, Canada. She received the B.Sc. (honors pure mathematics), B.Sc. (honors applied mathematics), and B.Mus. (piano performance with distinction) from the University of Calgary in 2000. She received the M.Sc. in mathematics from the University of British Columbia in 2003. She is currently pursuing her Ph.D. in geology and geophysics at the University of Hawaii at Manoa.

During her master's Miss. Nosal studied architectural acoustics. Her research focused on acoustical radiosity for room sound field prediction. Her current interests include underwater acoustics, inverse methods, signal processing, and parallel computing. Her main research is in the use of passive acoustics for the detection and localization of marine mammals.

Neil Frazer has a B.A.Sc. (1970) from the University of British Columbia in engineering physics and a PhD (1978) from Princeton in geophysics. He has been at the University of Hawaii at Manoa since 1979 where his present interests include signal processing, biosonar, and the population dynamics of macroparasites on wild fish and sea-cage farmed fish.

Editors Note: This is a reprint of the winning Student paper from the Student Poster Competition at the recent Oceans 2005 conference in Brest. Top left is a picture of Eva-Marie Nosal receiving the award at the banquet in Brest. Bottom left is another picture of her sitting at a table.

8th INTERNATIONAL SUBMARINE RACES

Kurt Yankaskas, Business Development, FURE
Claude Brancart, Senior Judge, ISR
Nancy R. Hussey, Executive Director, ISR
2318 Oak Drive Ijamsville, MD 21754

Abstract

The 8th International Submarine Races presents a design competition for underwater human powered submarines. This paper will discuss the events and efforts of the 2005 races. The paper will cover an overview of the 26 contestant teams' vehicles competing in the week-long, June, 2005 human-powered design competition at the David Taylor Model Basin, Naval Surface Warfare Center, Carderock, Maryland. Each team's technical report and presentation to the ISR judging staff is also available in digital format. A brief description and video of how the subraces are conducted in the test tank will be shown. It will be followed by a summary of the history of the event, including photos of past winners and their outstanding technical achievements and the outreach into engineering programs.

ISR History

The International Submarine Races was conceived with a single objective: engineering education. It does this via a design competition for human powered submarine races. Back in the late 1980's, business entrepreneur Hap Perry collaborated with the Ocean Engineering Department at Florida Atlantic University in Boca Raton in developing the idea of a human-powered submarine race. Engineering schools, research labs, corporations and individuals were invited to design, build and then bring their creations to Florida to test them in a race in the ocean at Singer Island. The first ISR was held in 1989 off Rivera Beach, Florida. During that first race, 16 teams from throughout the United States competed successfully, with the U.S. Naval Academy winning the overall prize.

A contestant member of that team said, "I learned more in actually building our submarine and making it work than in all my theoretical engineering classes put together." That contestant will always remember that eventful race. But more importantly it showed the challenges of creating an operating system from scratch that does what it's supposed to in the aquatic environment.

News media coverage of that first race was extensive, including a program on National Geographic Explorer that reached tens of millions of viewers worldwide through syndication and a front-page article in the Wall Street Journal, among hundreds of stories in print and on television.

The concept of an engineering design competition proved to be very popular, with 34 subs at the second ISR in 1991, when "Good Morning America" broadcast live from the beach, and then in 1993, when 44 teams came to Ft. Lauderdale to compete in ISR 3. That subrace took place in 20 feet of water one-quarter mile off the beach. Unfortunately, high winds and seas forced cancellation of several days of practice and competition, causing problems for the teams and our safety divers. Despite these setbacks, team morale and enthusiasm was high, and the races had demonstrated their technical and engineering merit.

Due to the combination of spiraling logistics, high costs and the unpredictability of weather and sea conditions, the original organizers opted to relinquish authority of the ISR to the Foundation for Underwater Research and Education (FURE), headed by Nancy Hussey, who has been the ISR Executive Director since 1989. The race organization was restructured by a dedicated group of veteran subrace volunteers.

Under FURE, ISR 4 was organized and conducted in 1995 in a controlled environment, at the U.S. Navy's Naval Surface Warfare Center's David Taylor Model Basin in Carderock, Maryland. The test tank there is 22 ft. deep, 51 ft. wide and 3,078 feet long. It holds 25 million gallons of water, and has proved to be an excellent venue for human powered submarine racing. Figure 1 shows the race course as it is laid out in the East end of the Model Basin. The drydock provides an excellent and safe means of launching submarines. The biennial 5th, 6th and 7th ISR subraces also were held there, with increasingly sophisticated designs and an extraordinary outpouring of creative energy.

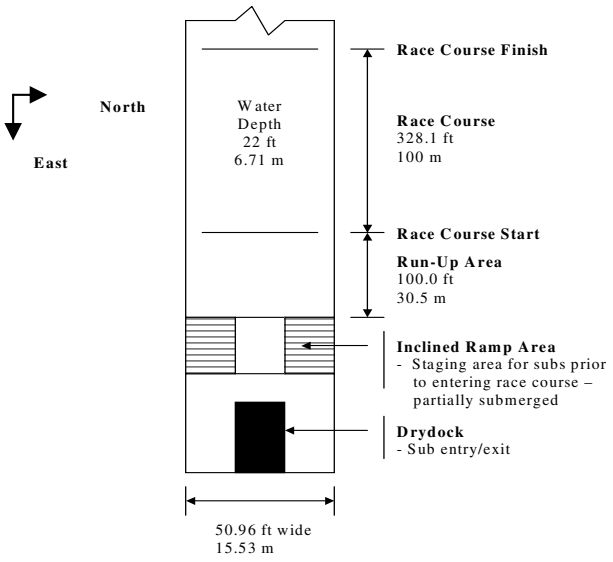


Figure 1. David Taylor Model Basin Race Course

Race organizers were so pleased with the facilities and cooperation from the U. S. Navy that they elected to hold all subsequent competition at David Taylor Model Basin. The 5th International Submarine Races™ were held June 23-27th, 1997, and saw human-powered records shattered. A streamlined submersible powered by a young Canadian ocean engineer streaked into the underwater spotlight, setting a new world speed record and pushing forward the frontiers of human-powered vehicle performance. The one-person sub, "OMER 3", piloted by Francois Maisonneuve from the University of Quebec's Ecole de Technologie Superieure in Montreal, achieved a speed of 6.97 knots (8 MPH) in a 10-meter measured course, shattering the previous mark of 6.69 knots set in 1996 by Californian Bill Nicoloff. Among the competitors was the first high school team and the first all-female crew in the nine-year history of the ISR.

ISR Organizers skipped 1999 but were back with the 6th subrace in 2001 and the 7th in 2003. Both events were extremely successful, expanding to more colleges, universities, private entrants and technological high schools. As the Navy and Carderock officials became increasingly comfortable with the event and confident about its details, the Navy's level of cooperation and support increased steadily. More than 150 volunteers provided resources required to conduct the races, including U.S. Navy Reserve divers and experts from the NSWC Carderock Division staff. Each commanding officer on whose watch the design competition has been held has extended a welcome hand of support, without which the ISR success could not have been possible.

The Submarines

ISR rules require that the one and two-person custom made submarines be "wet," meaning that their crews breathe on SCUBA. In a two-person sub, the pilot steers the vessel while the propulsor provides leg power through a variety of different drive systems, such as a bicycle chain drive hooked to a propeller. In one-person designs, a single individual provides both power and guidance. Each craft takes the team many hours to design, construct and test. It is important for each team to consider who will be their main propulsion.

The Contestants

Many teams receive financial backing from major university engineering departments, such as Michigan and Virginia Tech. Even with school support, teams resort to active and creative fundraising to provide the money needed to build and test their vehicle. Other initiatives represent the dreams of individuals, one of whom set a world record in his one-man sub. A team from a technological institute in Russia had to scrape up donations to try to get their sub flown to the U.S. in an Aeroflot jet. A Mexican team came all the way to the race site in Bethesda, Maryland, in a rented van. These young submariners, from many locations in the U.S. and abroad, represent the very best and most creative minds. Their enthusiasm spreads to all participants.

Figure 2. Typical Submarine Testing Conditions

ISR Safety

ISR operates with safety as the highest priority. SCUBA diving is an activity that many deem risky, however the training a SCUBA diver receives prepares individuals to operate in a foreign environment. ISR requires all in-water contestants to be certified SCUBA divers. The reserve dive units that the US Navy provides serve as safety divers for the race-course. Additionally, the Navy's Safety and Survivability Office provided a safety specialist to serve as Safety Judge. Civilian divers with years of experience provide in-water preparation. These volunteers use their experience to ensure the contestants complete the course safely.

Figure 3. Typical Race Conditions

It is in this environment that the contestants meet the challenges of having their design operate with humans at the controls.

The most significant risk since the beginning of the races has been viewed to be the potential for a serious in-water accident. This risk is managed by vigorous attention to details by race safety officials and by requiring that contestants demonstrate their Scuba certification and proficiency. For some contestants (recently SCUBA certified for the Races) this is their first time on low visibility, cold water. Veteran divers take them for a diver's skills review to ensure their comfort in the Navy's premier test facility prior to any race activities.

The David Taylor Model Basin at NSWC is a relative constant temperature of 59 degrees (F). This water temperature translates to needing a very good wetsuit. Otherwise, extended time in the water will lead to a very chilled diver. Accordingly, the safety team is on constant vigilance for cold racers. This is something the contestants are not always concerned with during the races. Another point is many of the contestants have spent tens of hours in their organization's pool ballasting and testing their design. Figure 2 shows a typical team in swim team pool. First one notices the excellent visibility and second the lack of a full wetsuit. The real world of the submarine races is starkly shown in figure 3. Visibility is significantly lower and the diver is clearly outfitted for cold water. The contestants' spirits rise to the challenges presented in a real world working environment. The successful team will have integrated its design with the capabilities of its dive team. The ISR committee requires each team to undergo very strict safety checks and in the water tests. Safety of all the contestants is the number one concern. To enhance the educational aspects to the entire submarine teams, each team was required to submit a technical report in double column format that included a detailed description of the concept formulation, design, construction, test, and project costs. The teams were then required to make a 20 minute executive presentation to a review board. Papers and presentations were ranked for awards. The papers and presentations were incorporated into a single 7th ISR CD. The CDs are given to all participants of the 7th ISR races, and are made available to future ISR contestants. This helps future ISRers to advance their designs to the latest technology and read design experiences.

ISR 8 Planning

The 7th ISR had 19 teams. This year, the initial inquiries exceeded 40. By the Spring 2005, the registered field has grown to 24 contenders. The Contestant Liaison, head judge Claude Brancart, who is the single point-of-contact for them. He provided to each team previous race information and coached each team in the preparation of their design, design report and race presentation. Given the size of the anticipated field, ISR 8 procedures were changed to improve the throughput within the confines of the facility. The goal is maximize the in-water time for reach team. To do so, staffing planned to conduct early safety inspections. These combined efforts resulted well-prepared teams ready to race when the race course was opened. The Model Basin provides a controlled environment ideal for conducting ISR. However, a 3078' long tank that is only 51 ft wide tends to drive the submarine designs to the underwater equivalent of a dragstrip racer, built for speed not maneuverability. The result is the previous four ISR races have been straight course speed runs. For the 8th ISR, we considered a slalom course to require some maneuvering capability by the submarine. It was planned to make the slalom course an optional event so that both teams and organizers can obtain some experience. Slalom gates were built to be easily handled by support divers yet do not pose a hazard to the submarines and crews. This event was planned to be conducted late in the race week. A certain portion of planning involves capturing the events and procedures that worked well. Those that did not, will be reworked to make ISR 8 an outstanding event. The staff and the course are ready to go.

ISR 8 Results

The 8th ISR was a complete success. The race was held from June 27 to July 1, 2005. One and two-person teams from the United States, Canada and the Netherlands battled it out against the clock in the week-long biennial event held at one of the world's largest indoor tanks. The participating teams were:

Everett Community College, WA

US Merchant Marine Academy

Sussex County Technical School, NJ

Virginia Tech

University of Maryland (2 subs)

Florida Atlantic University

University of Washington

Villanova University

Millersville University

University of Michigan

Ecole de Technologie Superiueure, Montreal

Ecole Polytechnique de Montreal

Texas A&M University

University of Delft, Netherlands

University of California at San Diego

San Diego High School

Independents: Don Burton, Bruce Plazyk (2 subs),

Wheaton Submarine Works (2 subs),

Steve Barton, David Johnson

New world speed records were set during race week in both men's and women's divisions of the International Submarine Races, an engineering design competition that challenges the creativity of underwater inventers and entrepreneurs. Omer 5, a sleek two-person submersible from the University of Quebec's Ecole de Technologie Superieure (ETS) in Montreal, Canada, set a new two-person speed record of 7.061 knots. The Canadians' women's team also set a new record of 5.885 knots.

The fastest high school speed mark was set by SubLime, a team from Spring Hill High School in Hernando County, FL, that clocked a run of 4.81 knots. A SubLime female team member also claimed the record speed, 4.828 knots, in the one-person design category.

The Judges awarded the top prize for the Best Overall Performance to a submarine called Wasub from the Technical University of Delft in the Netherlands. Placing second for overall performance was FA-U Boat from Florida Atlantic University, and third was SubLime, the high school team from Spring Hill, FL.

The top Innovation Prize went to Virginia Tech's Phantom 5. Finishing second and third were independent entrants Don Burton's Sparky's Sub and Bruce Plazyk's Faux Fish. Florida Atlantic University also won the "Smooth Operator" award, a prize given to the team with the most consistent performance, successful troubleshooting and ability to race the course.

Some of the hottest competition during the week was between Omer 5 and the new team from the Technical University of Delft. The event ended with a first-time ever, two-boat side-by-side duel between the two, won by Wasub. The Dutch sub ran straight and true while the faster Omer 5 took a commanding three-boat-length lead, only to miss the final gate and be disqualified. Both boats used computer-aided variable pitch propellers. Also the first time in ISR history, the event included a slalom course, in which submarines were required to maneuver through a set course of underwater pylons. The top three finishers were Wasub, Ol' Sarge II and FA-U Boat.

In other awards, Umptysquatch II, the team from the Sussex, N.J., Technical High School, won the prize for Best Use of Composites. The judges said the team used composite technology to create "special contour and surface variations necessary to achieve their vehicle's design requirements."

An award chosen by the nearly 300 sub team participants, the Spirit of the Races Prize, went to the team from the Technical University of Delft.

Wasub's 20-plus member team also won the prize for Best Design Outline. Teams must make a formal 20-minute technical presentation to ISR judges and submit a written outline of their design and construction program. This was the first year that TU Delft had competed in the races.

The SubLime high school team from Spring Hill, FL, was awarded the Judges' Prize, given in respect for sponsors Steve and Patricia Barton's many years of participation in the competition.

ISR 8 saw an increase in race speeds. In the two-person propeller academic category, Omer 5, 7.061 knots; FA-U Boat, 6.100; Archimede 3, Ecole Polytechnique de Montreal, 5.225. In the one person propeller category, Wasub, 6.903; Ol' Sarge II, Texas A&M, 5.382; and Sublime, 4.828. In the independent category, two teams from Wheaton, MD, Sub Works finished tops in their class, Scuba Doo Two at 4.642 knots and Sub Taxi, 3.897. In the non-propeller category, the academic winner was Manatee from the U.S. Merchant Marine Academy. The independent winner was Bruce Plazyk from Chicago.

Future Efforts

The Foundation for Underwater Research and Education (FURE) develops and promotes the marine technology education programs related to the International Submarine Races. For the past sixteen years FURE has worked with educators to define the educational content of the programs and to disseminate the knowledge attained through the subraces. This is accomplished through program planning and design workshops for potential contestants, museum and science center exhibits. These exhibits feature a human powered submarine story board, video documentary and a teacher's guides, "How to build a submarine". This material is intended to increase the understanding of the design technology by the general public. There is a special emphasis on early adolescents and participations in marine technology symposiums. The design information is targeted for both middle and high school students. The goal is spark the interest for these young students to pursue a marine engineering career. There is room for growth in this education process. Potential sites for the museum events include the science museums in the Jason network. Some in consideration are the Monterey Bay Aquarium, the Columbus (Ohio) Science Center, The Baltimore Aquarium, the New Orleans Aquarium, and the Living Seas exhibit at Disney World. A prospectus is being prepared. It will include the subrace event and related contestant workshops, the education and museum efforts. The thrust is on science and engineering principles and the technology underlying the submarines.

FURE welcomes all interested parties' involvement at any level of participation you find appropriate. The ISR organization is entirely volunteer, and eagerly seeks new talent to help with the many details of conducting the event and our educational program. It particularly encourages companies to get involved as sponsors or donors of in-kind services, supplies and equipment.

Conclusion

The benefits of the ISR have become obvious, and include a large number of teams and contestants who have had the opportunity to apply what they are learning, stimulate their creativity and take chances to be innovative. Once students graduate they are expected to succeed; this design competi-

tion allows them to experiment and see what happens, react, respond, repair, fix things that don't work and try again. Despite the serious competition, inter-team cooperation flourishes in the spirit of camaraderie that develops among peers. Friendships and positive relationships are forged, not only between participants but also with representatives of sponsoring companies, the Navy and our team of volunteers.

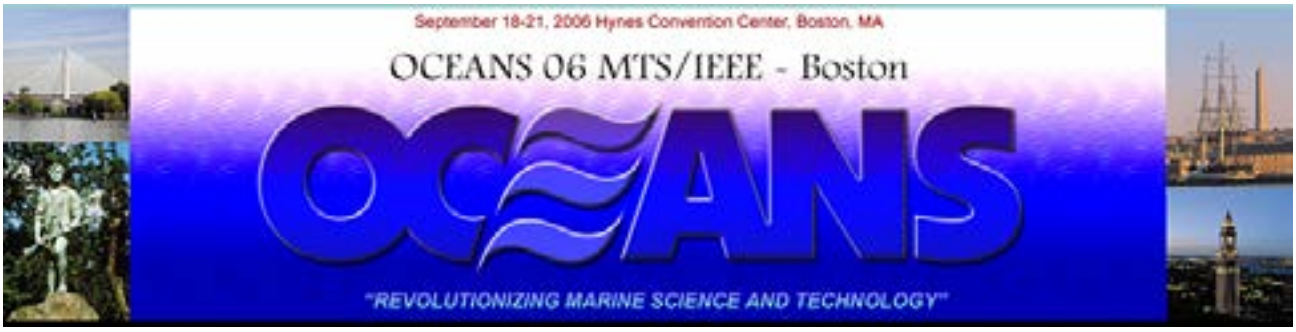
The International Submarine Races is a large-scale classroom into which are drawn the young engineers and entrepreneurs of tomorrow. We provide the opportunity for them to strive, to experiment and to excel. Typically, engineering students who participate in submarine design and competition are recruited even before graduation and go on to successful engineering careers.

As the ISR looks to the future, we see the continuation of our successful program and partnership with the U.S. Navy. In addition to the subrace, FURE will carry out an on-going educational initiative, reaching out to young people in high schools as well as colleges and universities. Thanks to a generous grant from the IEEE, we will be expanding our educational program, which will include engineering workshops for potential subrace contestants and presentations such as this.

Authors

Kurt Yankaskas, the Safety Judge for the ISR, is employed by the Human Systems Integration Directorate of the Naval Sea Systems Command (U.S. Navy). Mr. Yankaskas holds a BS in Ocean Engineering from Florida Atlantic University, and a BS in Biology from Rensselaer Polytechnic Institute. Claude Brancart is the Senior Judge for ISR, and is in a retired status. Mr. Brancart holds a B.A. in Math-Physics from Wesleyan University, Middletown, Connecticut, and a B.S. degree in Mechanical Engineering from the Massachusetts Institute of Technology in Cambridge, Massachusetts, both in 1958. In 1965 he received a M.S. degree in Mechanical Engineering / Fluids, and in 1969, he received a M.B.A. with honors, both from the University of Connecticut.

Nancy R. Hussey, the Director of the ISR for the past 15 years, is the President of the Foundation for Underwater Research and Education, and holds a BA in Geography from George Mason University.



The Oceans 06 MTS/IEEE-Boston Conference and Exhibition will be held in Boston Massachusetts from **September 18-21, 2006**. The birthplace of the American Revolution, Massachusetts and the surrounding New England region enjoys a centuries-old relationship with the ocean; from the fishing and whaling ports of Gloucester and New Bedford to the premier technology centers of the Woods Hole Oceanographic Institution and the US Navy's Undersea Warfare Center. Pleasant autumn weather and many tourist sites and activities, combined with a stimulating technical program, will make this Conference a memorable event.

The OCEANS 06-Boston technical program will continue to emphasize the traditional core areas of marine science and technology development. Researchers from academia, industry, and government are encouraged to submit their recent work on topics such as:

- Underwater Acoustics and Acoustical Oceanography
- Sonar Signal / Image Processing and Communications
- Ocean Observing Platforms, Systems, and Instrumentation
- Air and Space Ocean Remote Sensing
- Ocean Data Visualization, Modeling, and Information Management
- Marine Environment, Physical Oceanography, and Meteorology
- Optics, Imaging, and E-M Systems
- Offshore Structures and Technology
- Marine Law, Policy, Management, and Education

In addition, the Boston conference plans to highlight several "hot topic" areas of high current interest to the members of the MTS/IEEE research community:

- Homeland Security Applications
- Tsunami Early-warning Systems
- AUV/UUV/Glider Technology
- Distributed Sensors and Networks
- Tracking and Data Fusion
- Non-acoustic Sensing and Imaging
- Integrated Ocean Observatories
- Marine Mammal Classification
- Arctic Ocean Science
- Optical Properties of Water
- Aquaculture Engineering
- Marine Archaeology

Submissions should include a 500-1000 word extended abstract clearly outlining the technical contribution. All submissions will be competitively reviewed and judged on the basis of technical quality, novelty, and relevance to the technical program. Accepted contributions will be allotted a 20-minute oral presentation. Accepted student contributions will be allotted poster presentations accompanied by oral précis. On all accepted presentations, a minimum of one co-author must

be present and registered at the full conference registration fee. In addition, all presenters are required to submit a paper for publication in the archival proceedings not to exceed 6-pages, including figures. Final papers must be accompanied by proof of: 1) paid registration, 2) IEEE PDF eXpress compliance, and 3) copyright disclosure.

Please note the following important dates:

- **Revised** Abstracts Deadline: March 31, 2006
- Author Notification: May 15, 2006
- Paper Submission: July 15, 2006

Abstract submissions will be accepted on the conference web site starting January 1, 2006. Submissions must include title, each author's name and affiliation, and the technical area(s) and sub-area(s) into which the paper falls using the MTS/IEEE topics list published on the conference website. In order to assure accurate abstract handling, authors are encouraged to carefully examine the topics list and choose the technical area(s) that most closely match the area of their work. Further details regarding the electronic submission process will be available on the conference web site, www.oceans06mtsieeeboston.org.

The conference committee welcomes additional ideas for special session topics and tutorials. Please email your proposals to the committee at info@oceans2006americas.org. Special session proposals should include topic title, a short description of session emphasis and organization, and contact information of the prospective session organizer.

For additional **Technical Program** information contact Technical Program Chair: Dr. Vincent Premus, MIT Lincoln Laboratory at techchair@oceans2006mtsieeeboston.org or at (+1) 781-981-5341

For additional **Student Program** information contact Student Program Chair: Prof. Alexandra Techet, Dept. of Mechanical Engineering, Massachusetts Institute of Technology, at ahtechet@mit.edu or at (+1) 617-452-2266

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Stephen Greineder, NUWC
Christian de Moustier, UNH
David Pistacchio, NUWC
Henrik Schmidt, MIT

TECHNICAL PAPERS

The Technical Program Committee of Oceans'06 Asia Pacific is calling for contributions for scientific and technical papers. Contributions are invited in the form of an abstract of up to 2 pages to be submitted on-line (use the abstract-on-line button on the conference page). The areas of interest (non exclusive list) are listed in the conference web site http://www.oceans06asia-pacific.org.

Extended deadline for abstract submission: 6 January 2006
Notification of Acceptance: 15 February 2006
Final paper submission: 15 March 2006

Several special sessions are currently being planned, namely Acoustics Communications and Networks, Ambient Noise Imaging, Synthetic Aperture Sonar Processing, Underwater Vision-based Navigation, Bio-sonar, UNESCO IOC Tech Transfer guidelines, Asian Tsunami Warning System, Marine Environmental Engineering, Observations by AUVs and etc.

TUTORIALS

The Conference Committee invites proposals for half-day tutorials in accordance to, but not limited to the following themes:

- AUV/ROV Design
- Acoustic Communications and Networking
- Acoustics and Signal Processing
- Remote Sensing
- Disaster Management
- Marine Environment
- Underwater 3D Mapping
- Environmental Restoration

Submit a proposed course description of up to 1,000 words and your instructor biography of up to 300 words for review at www.oceans06asiapacific.org.

Proposal/Biography Deadline: 6 January 2006
Notification of Acceptance: 28 February 2006

STUDENT POSTERS

A student poster program will be held concurrently to encourage active participation of the next generation of ocean scientists, engineers, and technologists. Students at High School, Undergraduate and Graduate levels are invited to submit their abstracts and present their work at a special poster session. Guidelines and topics are the same as that for the Technical papers. Prizes will be awarded for the top students. Limited funds may be available upon application to support student attendance.

Extended deadline for abstract submission: 6 January 2006
Notification of Acceptance: 15 February 2006

EXHIBITION

The exhibition will be held at The Padang, Collyer Ballrooms & Raffles Foyer, Raffles City Convention Centre. Strategically positioned exhibition stands ensure delegates and speakers have every opportunity to visit you and your company representatives during refreshments and lunch breaks. Traffic is guaranteed as delegates will also have access to the exhibition before and after conference proceedings in the morning and in the evening. For more details on the Exhibition, please visit www.oceans06asiapacific.org.

The following Exhibition Packages are available:

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