

Report of Activities

Pacific Rim Workshop on Deep Ocean Power Science

Derek Dunn-Rankin, University of California, Irvine

This project was sponsor a workshop for Pacific Rim participants to attend a unique collaborative discussion exploring Deep Ocean Power Science, and particularly the potential future role that hydrates might play in energy-related aspects of the deep ocean. It is now well-recognized that a major storehouse of methane resides in deep ocean hydrates (i.e., ice cages with methane molecules trapped inside) and it is also well-recognized that these hydrates exist in many parts of the world, making them an energy resource for many nations without other fossil fuel alternatives. What is not well-understood is the potential for utilizing these hydrates for power generation. In addition, the deep ocean temperature and pressure environment is ideal for the formation of carbon-dioxide hydrates, and this might provide a means for sequestering carbon in order to reduce the emission of greenhouse gases. The workshop explored these issues from a multi-disciplinary and international scientific and technical perspective.

The workshop was held in Honolulu, Hawaii (at the center of the Pacific) and included 22 participants from Japan, Korea, Taiwan, and the United States. It covered fundamental and practical aspects of hydrate science. Half of the participants were student or young researchers. The workshop comprised invited lectures, research summaries, and a poster session. As the first of its kind, the workshop successfully identified important next steps in research into the combustion of methane hydrates and the opportunities for carbon-dioxide sequestration in hydrates. A follow-on workshop is being developed by participants from Taiwan.

Details of the first Pacific Rim Workshop on Deep Ocean Power Science, including the agenda and invited speakers, are attached.

A CD of the proceedings (including slides from presentations and posters from student presenters) was distributed to all participants and is available to the Pacific Rim program if desired.



February 23-26, 2014

**PACIFIC RIM WORKSHOP ON
DEEP OCEAN POWER SCIENCE**

Honolulu, Hawaii

The first workshop dedicated to an international discussion of the opportunities for advanced understanding of energy and power systems that might take advantage of the unique environmental conditions of the deep oceans.



Pacific Rim Workshop on Deep Ocean Power Science
 Sponsored by the University of California Pacific Rim Research Program
 February 23-26, 2014
 Honolulu, Hawaii

Deep Ocean Power Science
Meeting Agenda and Information

| Sunday, February 23, 2014 | | | |
|----------------------------------|---|--------------------------------|----------------------------------|
| Time | Topic | Location | Lead |
| 17:00 | Registration and Informal Welcome Gathering | New Otani Pacific Suite | Dunn-Rankin & Taborek |
| 19:00 | Dinner on your own** | | |

| Monday, February 24, 2014 | | | |
|----------------------------------|---|---|--------------------|
| Time | Activity | Location | Lead |
| 08:00 | Breakfast at hotel* | Hau Tree Lanai | |
| 09:30 | Meet buses for travel to Univ. of Hawaii | | |
| 10:00 | Introductions and Summary of Deep Ocean Power Science | East/West Center, UH | Taborek |
| 10:15 | Objectives for Workshop | | Dunn-Rankin |
| 10:30 | Invited Talk 1 – Carbon Sequestration | | Seeker |
| 11:15 | Discussion | | |
| 11:30 | Break for Lunch at UH Campus | | |
| 12:55 | Invited Talk 2 – Hydrate Fundamentals | | Ohmura |
| 13:35 | Discussion | | |
| 13:50 | Invited Talk 3 – Combustion of Hydrates | | Ueda |
| 14:20 | Discussion | | |
| 14:35 | Invited Talk 4 – Deep Drilling | | McKeever |
| 15:15 | Discussion | | |
| 15:35 | Break | | |
| 15:50 | Invited Talk 5 – Deep Ocean Power Research and HNEI | | Masutani |
| 16:35 | Discussion | | |
| 16:50 | Tour of UH facilities | | Masutani |
| 18:00 | Buses to hotel | | |
| 19:00 | Dinner at New Otani Kaimana | Sans Souci Room, New Otani Kaimana Hotel | |
| 21:00 | Hospitality Suite open conversation | | |

Contact: Derek Dunn-Rankin (ddunnran@uci.edu) with any questions or concerns



Pacific Rim Workshop on Deep Ocean Power Science

Sponsored by the University of California Pacific Rim Research Program

February 23-26, 2014

Honolulu, Hawaii

| Tuesday, February 25, 2014 | | | |
|-----------------------------------|---|-------------------------------|------------------------------------|
| Time | Activity | Location | Lead |
| 08:00 | Breakfast at hotel* | Hau Tree Lanai | |
| 10:00 | Buses to Hawaii Kai, Oahu | Molokai Room, HKGC | |
| 10:30 | Researcher Capabilities and Interests (~10 min. each) | " | Kwon, Chao, Li, Hayashi |
| 11:10 | Summary Discussion | " | |
| 11:20 | Poster Session | " | Researchers (all) |
| 12:00 | Hawaiian Lunch Buffet/Posters | " | |
| 14:00 | Keck Deep Ocean Power Science Laboratory | " | Karnani |
| 15:00 | Break | " | |
| 15:15 | Targeted Discussion – Futuristic Deep Ocean Power Science Ideas | " | Dunn-Rankin |
| 16:15 | Wrap-up/Homework Assignments | " | Taborek |
| 16:30 | Leave for social hour | Kona Brewing Co. | |
| 18:30 | Return to hotel; dinner on own** | | |
| 21:00 | Hospitality suite open for conversation | Pacific Suite | |

| Wednesday, February 26, 2014 | | | |
|-------------------------------------|---|---|-------------|
| Time | Activity | Location | Lead |
| 08:00 | Breakfast at hotel* | Hau Tree Lanai | |
| 09:30 | Plan for Day 3 | San Souci Room Kaimana Hotel | DDR |
| 09:45 | Prepare Discussion Reports | " | All |
| 10:45 | Reports from Subcommittees | " | All |
| 12:00 | Meeting closes – lunch on your own** | | |
| 14:00 | Executive Committee Summary Discussions | Pacific Suite | |
| | ALOHA | | |

* Breakfast is on your own schedule but charge to conference when eating at hotel


** These meals are on your own so you can explore your food interests as you like

Travel support from the National Science Foundation for young U.S. researchers is gratefully acknowledged – R. Chen, CTS Division, Engineering Directorate




Contact: Derek Dunn-Rankin (ddunnran@uci.edu) with any questions or concerns




Pacific Rim Deep Ocean Power Science Workshop


Featured Participants

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| Beei-Huan Chao | |
|  | <p>Beei-Huan Chao is Professor and Graduate Chair of the Mechanical Engineering Department at the University of Hawaii, Manoa. He received his Ph.D. from Northwestern University in 1987, and worked as a post-doctoral researcher at Princeton University from 1988 to 1992 before he moved to Hawaii. His research interests involve theoretical studies, primarily analytical by activation energy asymptotics, of various combustion phenomena such as ignition, extinction, propagation rate, stabilization and stability. His recent works focus on the enhancement of burning effectiveness and suppression of soot formation in diffusion flames through the redistribution of inert gas from the oxidizer to the fuel. Dr. Chao is also an enthusiastic teacher, receiving many teaching awards from his College and University.</p> |
| Yei-Chin Chao | |
|  | <p>Yei-Chin Chao received his Ph.D. degree from the School of Aerospace Engineering, Georgia Institute of Technology in 1984. Since then, Dr. Chao has been affiliated with Department of Aeronautics and Astronautics of National Cheng Kung University (NCKU), Taiwan. He has been a Distinguished Professor at NCKU since 2002. His research is in the areas of Combustion, Propulsion, Energy, Diagnostics, Thermal and Fluid Flows, and Acoustics. He received several national and international awards, including the Russell Severance Springer Professorship from the University of California, Berkeley. He has published more than 250 technical articles in well-established journals and conferences. He served as Department Chairman from 2001-2004 and as Director of the Aerospace Science and Technology Research Center (ASTRC) of NCKU from 2004-2011. He also served as the Chairman of the Aerospace Research Program of the National Science Council (NSC) in Taiwan during 2008-2011. He was the president of the Combustion Institute, Chinese Taipei Section during 2004-2008. He is currently Member of the Board of Directors of Institute of Dynamics of Explosion and Reactive Systems (IDERS).</p> |
| Derek Dunn-Rankin | |
|  | <p>Derek Dunn-Rankin is Professor and current Chair in the Department of Mechanical and Aerospace Engineering at the University of California, Irvine (UCI). He received his Ph.D. degree (1985) from the University of California, Berkeley, with an emphasis in combustion science. He was a post-doctoral researcher at Sandia National Laboratories Combustion Research Facility in Livermore until 1987, when he joined the faculty of Mechanical Engineering at UCI. Dr. Dunn-Rankin's research is in combustion and energy, droplet and sprays, applications of laser diagnostic techniques to practical engineering systems, with recent emphasis on electrical aspects of flames, and the direct combustion of methane hydrates. He received a National Science Foundation Presidential Young Investigator Award in 1989, the Society of Automotive Engineering Ralph R. Teetor Engineering Educator Award in 1991, a Fulbright Scholar Fellowship in 1997, a Japan Society for the Promotion of Science Fellowship in 2008, and the Oppenheim Prize of the Institute for the Dynamics of Explosions and Reactive Systems in 2013.</p> |

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| Koichi Hayashi | |
|  | <p>A. Koichi Hayashi is Professor in the Aerospace System Laboratory, Department of Mechanical Engineering at the Aoyama Gakuin University, Kanagawa, Japan. He received a Ph.D. (1980) from the University of Colorado, Boulder in the field of thermo-fluid science. He was a research associate at Princeton University in the field of combustion chemistry until 1982, when he joined Nagoya University, in the department of Aerospace Engineering, staying there until 1995 as an associate professor, when he moved to Aoyama Gakuin University, Tokyo as a professor. Dr. Hayashi's research includes combustion science, including detonation, supersonic combustion, combustion chemistry, ignition, methane hydrate combustion, and two-phase combustion flow, and fluid science such as supersonic hypersonic flow, and two-phase flow, experimentally and numerically. He received an Asahi Scientific Promotion Award in 1984, a Wactaw Cybulski Medal, Poland Academy of Science in 1997, and the Aoyama Gakuin Academic Award, Aoyama Gakuin University in 2012. He is an author of more than 300 scientific papers.</p> |
| Oh Chae Kwon | |
|  | <p>Oh Chae Kwon is Associate Professor of Mechanical Engineering at Sungkyunkwan University, Korea. He received his M.S. degree in 1994, from Seoul National University, Korea (Aerospace Engineering), and his Ph.D. in 2000, from the University of Michigan, Ann Arbor, USA (Aerospace Engineering). Kwon has been associated with theoretical and experimental research on combustion, fluid dynamics and heat transfer since 1990. Past activities include: flame/stretch interactions in premixed flames, the self-preserving properties of unsteady turbulent jets, microgravity combustion, and the combustion synthesis of carbon nanotubes. Recently, his research focus is on the fundamentals of microcombustion with applications in micro thermophotovoltaic power generation and micro fuel processing, the utilization of ammonia as a carbon-free fuel, the superadiabatic radiant porous burners, and the combustion and mixing characteristics of methane-oxygen bipropellants.</p> |
| Sunny Karnani | |
|  | <p>Sunny Karnani received his Ph.D in Mechanical and Aerospace Engineering at the University of California, Irvine (2011) studying the electrical aspects of small diffusion and partially premixed flames both experimentally and numerically. He is currently a project scientist at UC Irvine and is leading the development of the W.M. Keck Foundation Deep Ocean Power Science Laboratory.</p> |


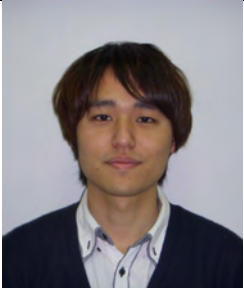


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| Yueh-Heng Li | |
|  | <p>Yueh-Heng Li is an assistant researcher in the Research Center for Energy Technology and Strategy (RCETS) at National Cheng Kung University (NCKU). He received his Ph.D. degree from National Cheng Kung University in 2008, and his background is in combustion and energy science. His Ph.D. work was related to the fundamentals of a small-scale liquid-fuel combustor design integrated with a combustion-driven thermophotovoltaic system. As a postdoctoral researcher from 2008 to 2012, his emphasis was on bio-energy and oxy-combustion research and technology. This energy work has broadened as the RCETS developed. Dr. Li is in charge of internationalization affairs in RECTS, included holding international conferences and coordinating academic visitations, acting as the EU national contact point (NCP) for the EU FP-7-People project, seeking international collaboration with universities/institutes, as well as facilitating the invitation of professors/researchers for short-term visits at NCKU. His current research includes participation in the project of oxy-coal combustion with CCS and in the methane hydrate combustion project from NSC-Taiwan.</p> |
| Stephen Masutani | |
|  | <p>Dr. Stephen Masutani, P.E., is a Research Professor at the University of Hawaii, Manoa (UHM). He is a member of the faculty of the Hawaii Natural Energy Institute, a research unit of the School of Ocean and Earth Science and Technology. Dr. Masutani graduated from the University of Hawaii with a B.S. in Mechanical Engineering in 1977. He earned his M.S. and Ph.D. in Mechanical Engineering from Stanford University in 1980 and 1985, respectively. In 1985, he joined the Hitachi Research Laboratory of Hitachi, Ltd. in Japan, working at the Coal Technology Center on multiphase flow combustion and the development of optical diagnostics for applications in coal combustors. In 1989, Dr. Masutani returned to Hawaii where he worked at the Pacific International Center for High Technology Research on ocean energy systems and ocean sequestration of CO₂, until joining the University of Hawaii in 1984. His areas of specialty include thermochemistry and kinetics, CO₂ sequestration, methane hydrates, deep oil spills, multiphase flows, combustion, and renewable energy systems.</p> |
| Steve McKeever | |
|  | <p>Steve McKeever is a practicing drilling engineer, currently working for a ConocoPhillips in Anchorage, Alaska. In his career he has worked as a roughneck, a driller, a tool pusher, an instructor at a roughneck school, a drilling equipment salesman, a completion tool hand, a civil engineer, a drilling engineer, a drilling superintendent, and an instructor of drilling engineering courses. His engineering assignments have included planning and operational support for extended reach multi-lateral oil wells, high rate horizontal gas wells and deep-water offshore exploration wells. Most of his experience has been in Alaska, with some experience in Wyoming and recently in Perth, Australia. He received a Bachelor of Science degree in Civil Engineering from the University of Alaska, Anchorage and a Bachelor of Arts degree in Anthropology and Film Studies from Dartmouth College.</p> |

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| Ryo Ohmura | |
|  | <p>Ryo Ohmura was born in Mishima City at the foot of Mt. Fuji, Shizuoka Prefecture, Japan. He obtained his B. Eng, M. Sc. and Ph. D. degrees at Keio University, working on Mechanical Engineering, specifically, thermal engineering aspects of clathrate hydrates. He worked in France joining the French project on naturally-occurring methane hydrates in 2000-2001. He then joined the National Research Institute of Advanced Industrial Science & Technology, working in Sapporo as a research scientist for four years. In 2006, he was appointed a senior assistant professor at Keio University where he is currently Associate professor of Mechanical Engineering. He was a recipient of the Young Engineers Award from the Japan Society of Mechanical Engineering. He has published more than 100 research papers. His interests are in the fundamental physical chemistry of clathrate hydrates as well as hydrate-based novel energy/environment technologies.</p> |
| Randy Seeker | |
|  | <p>Wm. Randall Seeker is the Chief Technology Officer at Calera Corporation where he manages the scale up and engineering of the Calera process for capture and conversion of CO₂ to carbonate cements and low energy chemical processes. Prior to joining Calera, he was the Manager, New Product Development at GE Environmental Services in Santa Ana, California. At GE, Dr Seeker was responsible for all new product and technology development for GE Environmental Services. He is an adjunct professor at the University of California, Irvine in the Mechanical and Aerospace Engineering Department where he developed a new course in Renewable and Sustainable Energy Systems. He has 35 years of experience in research and development, combustion technologies, air pollution control and monitoring, carbon capture and utilization, chemical synthesis technologies, waste treatment technologies and conventional and advanced power systems. Dr. Seeker received his Ph.D. in Engineering (nuclear and chemical) from Kansas State University. He served on the U. S. Environmental Protection Agency's Science Advisory Board for over 10 years and on several U.S. National Academy of Science panels. He has testified before U. S. Congressional committees on the results of his studies and he served on the Alternative Chemical Weapons Disposal Subcommittee of the NAS. Dr. Seeker has 34 US and International patents and over 60 published patents pending. He has over 200 technical publications (over 100 peer reviewed) on various aspects of the air pollution control from combustion systems.</p> |
| Peter Taborek | |
|  | <p>Peter Taborek is Professor and Chair in the Department of Physics and Astronomy at the University of California, Irvine (UCI) . He received his PhD from Caltech in Physics and spent several years working at AT&T Bell Labs and Texas Instruments before joining UCI in 1990. Professor Taborek is an experimental condensed matter physicist. He has worked on many condensed matter systems ranging from the wetting properties of superfluid helium near absolute zero to diamond film growth from plasmas and flames. His most recent projects include fluid pinch-off using high speed video, flow through nanometer-scale pipes , measurement of Casimir forces using an AFM, and growth of methane hydrates. He is a Mathematica enthusiast and has written an e-book on mathematical methods using Mathematica. He received the UCI Distinguished Faculty Award for Teaching in 2006 and is a Fellow of the American Physical Society.</p> |

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| Toshihisa Ueda | |
|  | <p>Toshihisa Ueda is Professor in the Department of Mechanical Engineering at Keio University, Kanagawa, Japan. Professor Ueda received his Bachelor of Engineering in 1976, his M.S. in 1978, and his Ph.D. in 1982, all from Keio University. He joined Keio University as a research assistant just after receiving his Ph.D. degree and then joined the faculty in 1986. He was Director of the Keio Leading Edge Laboratory of Science and Technology from 2008-2012. Professor Ueda is a member of the Japan Society of Mechanical Engineers (JSME); the Combustion Society of Japan; the Japan Society of Chemical Engineers; the American Physical Society; and the American Institute of Aeronautics and Astronautics. He has been a Director of the Japanese Combustion Institute since 2008 and a Fellow of the JSME since 2011. Professor Ueda's research field is reactive fluid dynamics, especially concerning mixing, reforming, and combustion. Recent topics include: combustion of methane hydrate, extinction of fire by carbon dioxide hydrate, concentration oscillations in premixed flames, the development of compact reformers for H₂, and chaotic mixing by static mixers.</p> |

Workshop Participants – Young Researchers

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| <p>Jeff Botimer</p>  | <p>Jeff Botimer, graduate student, University of California, Irvine</p> <p>Poster: Formation physics of hydrates</p> | <p>Guan-Bang Chen</p>  | <p>Dr. Guang Bang Chen, Associate researcher, Research Center for Energy Technology and Strategy (RCETS), National Cheng Kung University, Taiwan</p> |
| <p>Yu-Chien Chien</p>  | <p>Yu-Chien (Alice) Chien, graduate student, University of California, Irvine</p> <p>Poster: Electric field controlled diffusion flames</p> | <p>Daniel Kahoonei</p>  | <p>Daniel Kahoonei, graduate student, University of Hawaii.</p> <p>Poster: Weak jet diffusion flames with fuel supplied from a tube</p> |
| <p>Hiroataka Nakano</p>  | <p>Hiroataka Nakano, graduate student, Keio University, Japan</p> <p>Poster: Extinction of pool fire by carbon dioxide hydrate</p> | <p>Rosa Padilla</p>  | <p>Rosa Padilla, graduate student, University of California, Irvine</p> <p>Poster: Water-laden methane/air counterflow diffusion flames</p> |
| <p>Masanori Suemitsu</p>  | <p>Masanori Suemitsu, graduate student, Keio University, Japan</p> <p>Poster: Combustion of methane hydrate in natural convective condition</p> | <p>Michela Vicariotto</p>  | <p>Michela Vicariotto, visiting researcher to the University of California, Irvine from Politecnico, Milano, Italy</p> <p>Poster: Laser ignition of methane hydrates</p> |

| Fang-Hsien Wu | | Tomoki Yoshioka | |
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|  | <p>Fang-Hsien Wu, graduate student, National Cheng Kung University, Taiwan</p> <p>Poster: A preliminary study of methane hydrate release rate and combustion phenomenon with Tsuji burner</p> |  | <p>Tomoki Yoshioka, undergraduate student, Keio University, Japan</p> <p>Poster: Recent research on hydrate and combustion</p> |
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