12th International Business & Technology Summit

International Business and Technology Summit

Thermal Management of Electronics

Emerging Technologies for Advanced Cooling of Electronic Systems

coolingZONE

August 27-30, 2012 | Cambridge, MA

International Business and Technology Summit

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Overview

coolingZONE presents the 12th International Business and Technology Summit in Thermal Management of Electronics in Cambridge MA, USA on August 27-30, 2012. This event will feature world renown experts in thermal management to share their latest developments and research, and discuss emerging technologies for advanced cooling of electronic systems.

Engineers across the globe attend the Summit to learn what new cooling challenges will confront them, where the solutions will be found, and who can help them with effective products and services to manage today's thermal challenges.

The Summit's agenda includes two full days of technical presentations from leading experts in industry and academia. Short technical sessions will be provided by corporations who are advancing the thermal management community with innovative and practical thermal solutions.

Topics to be presented in Summit 2012 include:

- Transitioning From Air to Liquid Cooling: Strategies and Approaches
- Materials for Microelectronic Heat Dissipation
- Using Computers to Go Where Experiments Cannot: Massively-Parallel LES of Turbulent Heat Transfer
- Intra-chip Microfluidic Cooling - Gen3 Thermal Packaging Technology
- High-Performance Thermal Management Materials in Systems
- State of the Art in Thermal Management: What's New, What's Real and What's Bunk
- Best Practice in CFD
- Next Generation Embedded Liquid Cooling with Ultra Low Thermal Resistance
- Thermal Measurements in Electronics Cooling
- Simulating Natural Convection-Cooled Systems in a CFD Program
- Thermal Analysis of Multi-Junction IC Devices
- Micro- and Nano-Structured Materials to Enhance the Performance of Ultra-Thin Vapor Chamber

Who Should Attend?

Engineers, engineering managers and executives, chief technical officers, project managers, professors, students and others who want insight into the thermal design issues that affect product performance and the latest advancements in solving these critical thermal challenges

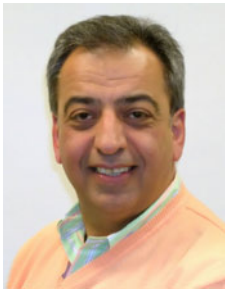
About the Speakers

Chris Aldham, Ph.D.

Dr. Chris Aldham has worked in computational fluid dynamics (CFD) for over 30 years (starting with PHOENICS at CHAM with Prof. Brian Spalding) and for more than 20 years in the field of electronics cooling. After 16 years at Flomerics, Chris joined Future Facilities as a Product Manager responsible for 6SigmaET – electronics cooling simulation software which is part of a suite of integrated software products that tackle head-on the challenges of data center lifecycle engineering (including equipment design analysis) through the Virtual Facility.

Mehdi Asheghi, Ph.D. CO-CHAIR

Dr. Mehdi Asheghi is currently a consulting associate professor at the Stanford University focusing on further development of PCRAM technology. He completed his Ph.D. (1999) and postdoctoral (2000) at the Stanford university conducting research in the area of nanoscale thermal engineering of microelctronic devices. He is also with the iCONA Technology, which is a Palo Alto based research and development firm focusing on smart energy and thermal managements of residential buildings. He led a well-known and funded research program (2000-2006) at the Carnegie Mellon University that focused on nanoscale thermal phenomena in semiconductor and data storage devices. He is the author of more than 110 book chapters, journal publications and fully-reviewed conference papers.



Kaveh Azar, Ph.D.

Dr. Kaveh Azar is the President and CEO of Advanced Thermal Solutions, Inc. (ATS), a leading edge thermal management company involved in developing liquid and air cooling solutions for the telecomm and computing market sectors. Under Dr. Azar's leadership, ATS has expanded globally with offices in Europe and Asia, and has become the leading supplier of cooling solutions and thermal management consulting to the telecomm market sector. Prior to ATS, Dr. Azar was the founder and manager of Lucent Technologies thermal management center, responsible for developing the next generation of cooling systems. In addition, Dr. Azar has authored Lucent's thermal roadmap and served as the corporate thermal consultant. While at Lucent, he developed a state-of-the- art thermal/fluids laboratory for simulation of components, boards and systems. Since 1985, Dr. Azar has been an active participant in electronics thermal community and has served as the organizer, general chair and the keynote speaker at the national and international conferences sponsored by ASME, IEEE and AIAA. He has also been an invitee to national bodies such as NSF, NIST and NEMI for organizing government and industry research goals in electronics cooling. Dr. Azar has been an adjunct professor at a number of universities in the USA, and lecturers worldwide on different facets of electronics cooling. He holds more than 31 national and international patents, has published more than 73 articles, 3 book chapters and a book entitled, "Thermal Measurements in Electronics Cooling" and has edited a 5 book series, "Qpedia – Electronics Thermal Management." In addition, he served as the Editor-in-Chief of Electronics Cooling Magazine for eleven years, and is currently the publisher of Qpedia, a monthly publication dedicated to thermal management of electronic systems. Dr. Azar has received several recognitions within Bell Labs and other entities that include Bell Labs' President Silver Award, Strathmore's Who's Who, The Uptime Institute for Visionary Leadership and IEEE SEMITHERM Significant Contributor Award in thermal management of electronics systems.

Ruben Bons

Ruben Bons is the Electronics Sector Manager with CD-adapco, responsible for understanding and addressing the market needs of electronics thermal management applications with STAR-CCM+. He joined CD-adapco about 1 year ago after previously working for Structural Research & Analysis Corporation and Blue Ridge Numerics. Ruben has spent more than 15 years using, supporting, and selling a wide range of simulation programs including structural, thermal, flow, kinematic, and electromagnetic analyses. For the past 8 years most of his work has focused on the application of CFD to electronics thermal management. Ruben Bons is based in southern California in the United States.

Avram Bar-Cohen, Ph.D. KEYNOTE

Dr. Avram Bar-Cohen is a Program Manager in the Microsystems Technology Office of the Defense Advanced Research Projects Agency (DARPA), Arlington, VA; he is serving in this capacity while on leave from his position as a Distinguished University Professor at the University of Maryland, where he most recently also served as the Chair of the Mechanical Engineering Department (2001-2010). Bar-Cohen earned a PhD in mechanical Engineering from the Massachusetts Institute of Technology and prior to joining Maryland, Bar-Cohen directed the University of Minnesota's Center for the Development of Technological Leadership and held the Sweatt Chair in Technological Leadership. His publications, lectures, short courses, and research, as well as professional service in ASME and IEEE, have helped to create the scientific foundation for the thermal management of electronic components and systems and pioneered techniques for energy-efficient sustainable design of manufactured products. Dr. Bar-Cohen has received numerous awards, including the prestigious International Centre for Heat and Mass Transfer's 2008 Luikov Medal, ASME's Heat Transfer Memorial Award (1999), and the IEEE CPMT Society's Outstanding Sustained Technical Contributions Award (2002). He is among a very select number of ASME Honorary Members and is a Fellow of IEEE.

Deborah Chung, Ph.D.

Dr. Chung is National Grid Endowed Chair Professor (since 1991), Director of the Composite Materials Research Laboratory (since 1989) and Professor of Mechanical and Aerospace Engineering (since 1986) in SUNY/Buffalo. She was Associate Professor of Metallurgical Engineering and Materials Science (1982-86) and Assistant Professor (1977-82) in Carnegie Mellon University. She holds a Ph.D. degree (1977) in Materials Science and an S.M. degree (1975) from M.I.T., and an M.S. degree in Engineering Science (1973) and a B.S. degree in Engineering and Applied Science (1973) from California Institute of Technology. Awards received include the Charles E. Pettinos Award from the American Carbon Society (2004), Chancellor's Award for Excellence in Scholarship and Creative Activities from SUNY (2003), Outstanding Inventor Award from SUNY (2002), Fellow conferral from American Carbon Society (2001) and ASM International (1998), "Teacher of the Year" Award from Tau Beta Pi (1993), Teetor Educational Award from the Society of Automotive Engineers (1987), Hardy Gold Medal from American Institute of Mining, Metallurgical, and Petroleum Engineers (1980), and Ladd Award from Carnegie Mellon University (1979). Her authored books include Carbon Fiber Composites (Butterworth, 1994), Composite Materials for Electronic Functions (Trans Tech, 2000), Applied Materials Science (CRC Press, 2001), Composite Materials (Springer, 2003) and Multifunctional Cement-Based Materials (Marcel Dekker, 2003). She has authored or coauthored almost 500 papers that have been published in journals. In addition, she has authored 5 encyclopedia articles and has edited two books, which include Materials for Electronic Packaging (Butterworth, 1995). Moreover, she is the inventor of 15 patents and has given over 200 invited lectures. Her research has covered many materials, including lightweight structural materials, construction materials, smart materials, electromagnetic materials, thermal management materials, electronic packaging materials, adsorption materials, battery electrode materials and solar cell materials.

Andrew Duggleby, Ph.D.

Dr. Andrew Duggleby is Assistant Professor of Mechanical Engineering at Texas A&M University and the Director of the Fluids, Turbulent, and Fundamental Transport Lab (FT2L) at Texas A&M, Mechanical Engineering. Dr. Duggleby earned B.S. degrees in Mechanical Engineering and Physics from Texas A&M University. He earned his M.S.E., with specialization in Computational Fluid Dynamics from University of Texas, and his Ph.D. in Mechanical Engineering from Virginia Polytechnic Institute. Dr. Duggleby's research interests include the development and implementation of high performance computer diagnostic techniques and mathematical analysis of data rich flow field results generated by experimental and numerical investigations of fluids, heat transfer, and plasmas, with application towards the understanding of the mechanisms, physics, and control of turbulence, patiotemporal chaos, and transport phenomena.

Norbert P. Engeleberts

Norbert P. Engelberts is the director of Advanced Thermal Solutions Europe and has been actively involved in electronics cooling since 1992. Prior to ATS, Engelberts headed the Thermal Design and Environmental Testing Group for Bell Labs, Lucent Technologies (now Alcatel-Lucent). During his 11 year tenure at Bell Labs, he was responsible for the thermal management and environmental testing (indoor and outdoor) of all telecommunications system equipment developed by the company in the Netherlands. In addition, Engelberts also brings with him expertise in HVAC system design, particularly those that house telecommunications and networking equipment. He works as a senior consultant for marked leading companies in the area of semiconductor, telecom, military, automotive and lighting. He has an extensive experience in the thermal management of LED based lighting solutions for a variety of applications, including automotive, street lighting, led replacement lamps.

Michael Ohadi, Ph.D.

Michael Ohadi, is a Fellow, ASHRAE, is professor and co-director, Center for Environmental Energy Engineering, Department of Mechanical Engineering, University of Maryland, College Park, Md. Dr. Ohadi is a member, ASME Nominating committee; Member and past Chairman, ASME Process Industry Division Executive Committee; Chairman, ASHRAE TC 8.4 Committee, Refrigerant-to-Air Heat Exchangers; Technical Associate Editor, Journal of Enhanced Heat Transfer; Technical Associate Editor, ASME Journal of Manufacturing and Science Engineering; Member, Advisory Editorial Board, Scientia, International Journal of Science and Technology. His research interests include: Heat and mass transfer at the meso, micro and nano-scales with applications to thermal/fluid system miniaturization, smart heat exchangers, electronic cooling, and innovative energy systems.

Alfonso Ortega, Ph.D. CO-CHAIR

Dr. Alfonso Ortega is the James R. Birle Professor of Energy Technology at Villanova University and Associate Dean for Graduate Studies and Research for the College of Engineering. He received his B.S. in 1976 from The University of Texas-El Paso, and his M.S. and Ph.D. from Stanford University in 1978 and 1986 respectively, all in Mechanical Engineering. He was on the faculty of Aerospace and Mechanical engineering at The University of Arizona from 1988 to 2005 where he founded and directed the Experimental and Computational Heat Transfer Laboratory. From 2004 to 2006, Dr. Ortega was the Program Director for Thermal Transport and Thermal Processing in the Chemical and Transport Systems Division of The National Science Foundation in Arlington, Virginia. He joined the faculty of Mechanical Engineering at Villanova University in 2005. Dr. Ortega directs the Laboratory for Advanced Thermal and Fluid Systems conducting research in the heat transfer and fluid mechanics fundamentals of convective heat transfer in single and two phase flow, especially in problems that arise from the technology of electronics thermal management, gas turbine cooling, and alternative energy technologies. He has supervised nearly 40 M.S. and Ph.D. candidates to degree completion and is the author of over 300 journal and symposia papers. Dr. Ortega is a Fellow of the ASME and is currently Associate Editor of the ASME Journal of Heat Transfer.

Alan W. Wong, Ph.D. KEYNOTE

Dr. Wong joined Aavid Thermalloy in 2007 as President and Chief Executive Officer. He brings to Aavid Thermalloy over 20 years of hands-on management experience in the design and manufacture of technology products (including flexible printed circuits & assemblies, hermetic seals & connectors, micro-electronic packages, solar PV cells and modules) for major OEM's in the U.S. and around the globe. Mr. Wong has extensive product and market knowledge in a wide range of high-reliability, high-precision applications in computers, consumer electronics, telecommunication, automotive, military-aerospace, industrial, medical, power and energy. He started his professional career at one of the "Big Four" international consulting/accounting firms in Los Angeles and was President and CEO of Parlex Corporation in Massachusetts prior to joining Aavid Thermalloy. Mr. Wong also serves on the board of directors of IPC, one of the largest industry associations representing major electronics firms in the U.S. Mr. Wong graduated from the University of Wisconsin, received post-graduate training in engineering and holds an MBA from UCLA and a Juris Doctor from Loyola Law.

Carl Zweben, Ph.D.

Dr. Zweben, now an independent consultant, has directed development and application of advanced electronic packaging and thermal management materials for over 35 years. His group at GE was the first to use Al/SiC (silicon-carbide-particle-reinforced aluminum) and other advanced materials in electronics and photonics. He was formerly Advanced Technology Manager and Division Fellow at GE Astro Space, where he directed the Composites Center of Excellence. Other affiliations have included Du Pont, Jet Propulsion Laboratory and the Georgia Tech National Science Foundation Packaging Research Center. Dr. Zweben was the first, and one of only two winners of both the GE One-in-a-Thousand and Engineer-of-the-Year awards. He is a Life Fellow of ASME, a Fellow of ASM and SAMPE, an Associate Fellow of AIAA, and has been a Distinguished Lecturer for AIAA and ASME. He has published and lectured widely on advanced thermal management materials, and is co-editor-in-chief of the six-volume Comprehensive Composite Materials. Dr. Zweben's clients have included numerous government agencies and major corporations, including Nokia, Delphi Electronics, Coherent Laser, Lumileds, Beacon Power, Themis Computer, Boeing, Hughes, ITT, General Dynamics, Northrop Grumman Laser Systems, COM DEV, GE Advanced Materials, GrafTech, Advanced Diamond, BP-Amoco, Ciba-Geigy, k-Technology, Zyvex Corporation, Poco Graphite, Princeton University High Energy Physics Group, and many others. He has taught over 250 short courses in the US, Europe and Asia. He also has been an expert witness for Seoul Semiconductor and other organizations.

Summit Program

Wednesday, August 29, 2012

7:30 Registration Opens/ Breakfast

8:00 Welcome

8:15 Keynote Address

Intrachip Microfluidic Cooling - Gen3 Thermal Packaging Technology

Avram Bar-Cohen, Ph.D.
Program Manager, DARPA-Microsystems Technology Office

From the dawn of the Information Age thermal management technology has played a key role in the continuing miniaturization, performance improvements, and higher reliability of electronic systems. During the past 65 years, thermal packaging has migrated from ventilation and air-conditioning to cabinet cooling, to package cooling with heat sinks and cold plates, and is today addressing on-chip hot spots and near-junction thermal transport. Following a brief history of thermal packaging, attention will turn to a review of emerging DARPA-driven micro- and nano-technologies for reducing the thermal resistance of defense electronic systems. The asymptotic maturation of current technology and growing thermal management demands in high performance computing and RF systems have led DARPA to initiate efforts in third-generation thermal management technology based on intrachip and interchip microfluidic cooling. The motivation, technological thrusts, and promise of this new thermal management paradigm will be discussed.

9:15 Technical Presentation

9:45 Break - Exhibitor Hall Open

10:00

Materials for Microelectronic and LED Heat Dissipation

Deborah D.L. Chung, Ph.D.
Director, Composite Materials Research Laboratory
Niagara Mohawk Chair Professor of Materials Research
Professor of Mechanical and Aerospace Engineering
University at Buffalo, State University of New York

Overheating is one of the biggest problems in the microelectronic and LED industries, as it limits the power, reliability, performance and further miniaturization. This problem particularly affects high-performance and high-power devices. For heat dissipation from a hot surface, heat needs to flow from the hot surface to a heat sink or a heat spreader. A heat sink is a thermal conductor that has a considerable heat capacity so that it serves as a sink for the heat. A heat spreader is a thermal conductor that serves as a conduit to channel the heat away from the heat source. Heat is dissipated from both heat sink and heat spreader to the environment. Suitable thermal insulation to avoid the dissipated heat to degrade nearly electronic components is often needed. Due to the low thermal expansion coefficient of semiconductors and their substrates, a low thermal expansion coefficient is preferred for the heat sink/spreader; otherwise, thermal fatigue may occur upon temperature cycling. The effectiveness of the heat flow from the heat source to the heat sink/spreader is partly governed by the quality of the thermal contact between the heat source surface and the surface of the heat sink/spreader. Improvement of the thermal contact requires a thermal interface material, which needs to be conformable. Conformability is essential due to the need to displace the air from the interface between contact surfaces that are necessarily not completely smooth. As long as the thermal conductivity exceeds that of air, a highly conformable thermal interface material is able to improve a thermal contact. A heat spreader can be isotropic or anisotropic; the latter has a low through-thickness thermal conductivity but a high in-plane thermal conductivity and has the advantage of providing some degree of thermal insulation so that the heat evolved does not affect the nearby electronic devices. The performance of isotropic and anisotropic heat spreaders depends on both the material and the dimensions, as shown by a heat conduction model.

11:00

Technical Presentation

11:30

State of the Art in Thermal Management – From Vacuum Tube to Super Computers

Kaveh Azar, Ph.D.
President and C.E.O, Advanced Thermal Solutions, Inc.

Thermal management, more than ever before, has become the center of attention in a successful launch of a product. The challenge that we all face as product managers or engineers is to select, design or deploy a successful cooling solution suitable for the product at hand while meeting its market requirements. As the result, we often overlook what is available on the market and what has been developed to meet the cooling challenges of different electronics. The range of cooling options varies from natural convection in air to cryogenic cooling – or any other solution that lies in between. In this presentation, the cooling technologies that have been developed across the electronics market sector – ranging from consumer electronics to high capacity computing to military/avionics equipment, will be presented. The use and reason behind deployment of such cooling technologies along with their salient points will be discussed. The presentation will close with the options to exercise when selecting a cooling system while highlighting the best path for meeting the market requirements of a given electronic system.

12:30 **Lunch- Exhibit Hall Open**

1:30 **Technical Presentation**

2:00 **Indirect Liquid Cooling of Electronics with Micro- and Mini-Scale Cold Plates and Heat Sinks: Theoretical and Practical Implications for Enhanced Cooling and Energy Recovery**

Alfonso Ortega, Ph.D.
James R. Birle Professor of Energy Technology
Associate Dean for Graduate Studies and Research
Director, Laboratory for Advanced Thermal and Fluid Systems
College of Engineering, Villanova University

Indirect liquid cooling via cold plates and liquid cooled heat sinks has become a necessary part of the potential design space for cooling electronic systems as the thermal margin for air cooling vanishes. In high density Data Center applications, liquid cooling offers the possibility not only of enhanced cooling, but also increases the potential for waste energy recovery. As liquid cooled solutions start to seriously contend for implementation, understanding their behavior will lead to better design processes, tools, and ultimately optimized solutions. This lecture will focus on understanding the basic behavior of liquid cooled heat sinks and cold plates, in single and two-phase flow. We will compare the various metrics that can be used to assess their performance, including the overall thermal resistance and the heat exchanger effectiveness. Finally, we will discuss the use of analysis tools in their design in particular to show the value of simple modeling approaches compared to full CFD approaches.

3:00

Break - Exhibitor Hall Open

3:15

Next Generation Embedded Liquid Cooling with Ultra Low Thermal Resistance

Michael M. Ohadi, Ph.D.
Professor of Mechanical Engineering and Director of Advanced Thermal Management Laboratory
CALCE Electronics Systems and Products Center
Department of Mechanical Engineering, University of Maryland

The demand for increased functionality of electronic products and the simultaneous trend of smaller feature size continue to raise dissipated power and the resulting power densities in electronic systems, introducing new challenges and opportunities in thermal management of modern electronics. Successful next generation thermal management systems will have to mitigate thermal limitations on the operation of high performance electronic systems to satisfy the increasing market demand for faster, smaller, lighter, and more energy efficient and cost effective products. The next generation cooling systems will integrate the thermal management techniques into the chip layout, and/or package design, to provide substantially enhanced cooling performance with ultra-low thermal resistance between chip-level heat generation and system-level heat removal path. This presentation will review most recent progress in embedded micro cooling systems, including use of use of thin film micro channel cooling. The technique involves utilization of 3-D structures and a distributed liquid delivery, with dedicated channels for vapor and liquid to maximize phase change heat transfer while facilitating isothermalization of the surface and minimizing the pressure drops and the associated pumping power requirements. Record-high heat transfer coefficients have been experimentally demonstrated with heat removal capability in excess of 1 kW/cm^2 and heat density of 1 kW/cm^3.

4:15

Technical Presentation

5:00

Day 1 Closing Remarks

Summit Program

Thursday, August 30, 2012

7:30 Registration Opens/ Breakfast

8:00 Welcome

8:15 Keynote Address

State of the Thermal Management Market

Alan Wong, Ph.D.
President and C.E.O, Aavid Thermalloy, LLC.

Abstract Coming Soon

9:15 Technical Presentation

9:45 Break - Exhibitor Hall Open

10:00 High-Performance Thermal Management Materials

Carl Zweben, Ph.D.
Advanced Thermal Materials Consultant
Life Fellow, ASME; Fellow, SAMPE & ASM; Associate Fellow, AIAA

In response to well-recognized needs, there have been revolutionary advances in thermal management materials. Silicon carbide particle-reinforced aluminum (Al/SiC), which was first used in thermal management by the speaker's group at GE in the 1980s, is now well established. By replacing a copper base plate with Al/SiC, one IGBT supplier "eliminated solder fatigue", extending guaranteed life from 10 to 30 years. There are an increasing number of new materials with low coefficients of thermal expansion (CTEs) and low densities having thermal conductivities up to 1700 W/m-K. Some are cheaper than traditional materials. Payoffs include: increased reliability; reduced junction temperatures and weight; low-CTE, thermally conductive PCBs, potentially eliminating the need for underfill; CTE matching allows direct attach with hard solders, reducing thermal resistance and solder fatigue. There are a large and increasing number of microelectronic and optoelectronic applications, including: PCBs and PCB cold plates; heat sinks; microprocessor, RF and power modules; heat spreaders and sinks; LED and laser diode modules; thermoelectric coolers; plasma and LCD displays; detectors; and photovoltaics. This presentation covers the large and increasing number of advanced thermal management materials, including properties and the growing array of applications.

11:00 Technical Presentations

12:30 Lunch- Exhibit Hall Open

1:30 Technical Presentation

2:00 Using Computers to Go Where Experiments Cannot: Massively-Parallel LES of Turbulent Heat Transfer

Andrew T. Duggleby, Ph. D.
Assistant Professor, Department of Mechanical Engineering, Texas A&M University

For decades, the steady increase in modern computing technology has allowed for faster as well as larger, more complex simulations. With all this computing power, there are still only two areas in which a numerical simulation is better than an experimental data: (1) quick, reliable (610-20% error) simulations for design optimization, and (2) massive resolution, highly accurate (< 1% error) simulations. In both cases the computer is going where experiments cannot. In quick simulation case, the simulations are faster and cheaper than any experiment, yielding results (hopefully trustworthy results) fast enough to be included in a design cycle. In the highly-resolved case, the resolution is far beyond any experimental measurements - in the context of turbulent heat transfer, the entire velocity, pressure, and temperature fields are known everywhere at all times. In this talk, the current state-of-the-art for both the quick simulations and the highly- resolved simulations will be discussed in the context of turbulent heat transfer. For the quick simulations, recent advances in not just simulation time, but total CAD to analysis time will be discussed: (a) Computer-Aided Design (CAD) model to mesh time, (b) simulation time, (c) accuracy vs time trade-os (models, resolution, etc), (d) analysis time. For computational fluid dynamics and heat transfer, this almost always refers to the steady-state Reynolds-Averaged Navier-Stokes (RANS) models, but an example will be given for a time-dependent Large Eddy Simulation of a venturi nozzle where CAD to analysis was done in under 24 hours. For the highly-resolved simulations, analysis techniques to elucidate useful information out of terabytes of data are discussed, with an example of pin-n heat transfer direct numerical simulation (DNS) where the modes responsible for heat transfer are extracted via Proper Orthogonal De-composition (POD), and then enhanced by endwall contouring resulting in increased convection with minimal drag increase.

3:00 Break - Exhibitor Hall Open

3:15 Next Generation Embedded Liquid Cooling with Ultra Low Thermal Resistance

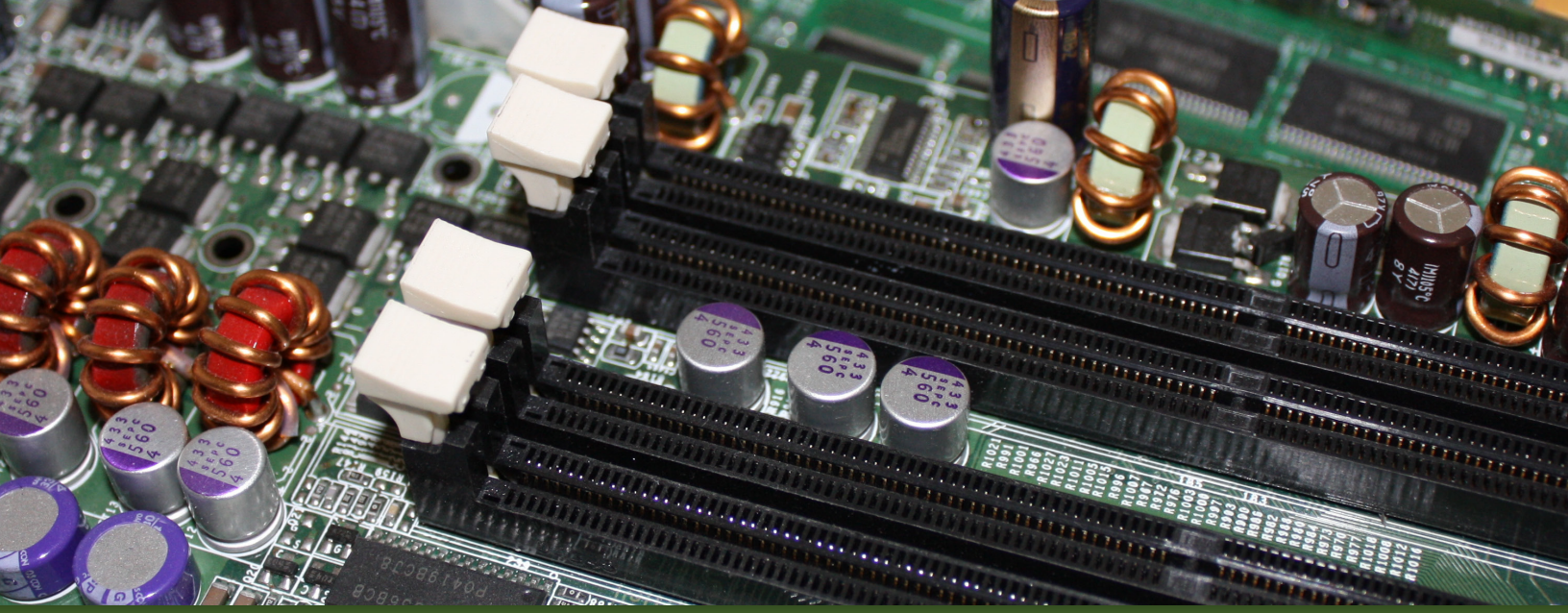
Mehdi Asheghi, Ph.D.
School of Engineering, Stanford University,

Abstract Coming Soon

4:15 Panel Discussion

5:00 Day 2 Closing Remarks

Presentation times subject to change in the event of unforseen events. In the event of change, updated schedules will be provided at registration.



Pre-Summit Short Course

August 27, 2012 | Cambridge, MA

Thermal Measurement and Experimental Design in Electronic Systems

Kaveh Azar, Ph.D.
President and C.E.O of Advanced Thermal Solutions, Inc.

Thermal management of electronic system, like any other problem, requires two independent solutions. One such solution is measurement. This tutorial is offered to familiarize the audience with the basic principles of measuring temperature, velocity, and pressure and heat flux in electronics systems. The tutorial will cover a host of topics in thermal measurement and uncertainty analysis along with the assessing the role of bad data in product design. The course is closed with a live and hands-on demo of how to use such sensors and measure T, V, P and heat flux sensors in wind tunnel testing of heat sink and PCB.

Goal

To provide the participants with the best practice of thermal measurement in electronics application and provide a hands-on experience on these best practices.

Who Should Attend?

Managers and engineer's engaged in the design of electronic systems which require measurement for design verification and subsequent product release.

How to Register

The cost to attend the day-long short course program on August 27, 2012 is $795.00, with a discounted rate of $695.00 if registered by July 31, 2012. Space is limited and advanced registration is required.

To register for the short course, please visit www.coolingzone.com
For more information, please contact 508-329-2021 or registration@coolingzone.com

Course Agenda

The seminar runs from 8:00 a.m. to 5:30 p.m. and includes a continental breakfast, lunch, and afternoon refreshments.

Introduction to Measurement

- What is electronics cooling and why we need to measure?
- Electronics system and the role of packaging as it relates to measurement.
- Impact of bad data on product delivery?
- Where we need to measure – an analytical approach to identify measurement points.
- Role of uncertainty in measurement.

Measuring Thermal Parameters

- Temperature Measurement – review the basic process of measurement and understand the pitfalls and the required approaches.
    - o Sensors for Temperature Measurement
        - ▫ Thermocouple
        - ▫ Thermistor and RTD
        - ▫ Diode
        - ▫ Liquid Crystal Thermography & IR
        - ▫ Optical probes
    - o Comparison of Liquid Crystal Thermography (LCT) and IR Systems
    - o Application of Temperature Sensors in Electronics Cooling Problems
- Velocity measurement in electronic systems
    - o What are fluid velocity and its role in cooling?
    - o Principle of velocity measurement.
    - o What is calibration and how it is done?
    - o Review of techniques and sensors for velocity measurement
        - ▫ Pitot tube- calibrated nozzles
        - ▫ Hot wire anemometers
        - ▫ Particle tracing with video systems
        - ▫ Laser Doppler Velocimetry (LDV)
        - ▫ Particle Image Velocimetry (PIV)
        - ▫ Air velocity measurement in electronic systems using hot wire anemometers.
- Pressure measurement in electronic systems
    - o Definition of pressure
    - o Pressure sensors
        - ▫ Manometers
        - ▫ Dial gauges
        - ▫ Electronic transducers
    - o Pressure calibration – low and high pressure

- Heat flux measurement in electronic systems
    - o What is heat flux and why measure it?
    - o Heat flux sensors
    - o Heat flux sensor calibration
- LED light and temperature measurement

Testing Systems or PCBs in Thermal Chambers

- Understanding operation of thermal chambers
- Airflow distribution in thermal chambers
- Impact of chamber flow on thermal measurement and system response.
- Required measures in setting up tests in thermal chambers

DEMO: Hands-On Testing in a Wind Tunnel of Pressure, Temperature and Velocity Measurements

- Heat sink characterization
- PCB thermal measurement - pressure, temperature and velocity profile
- Role of component placement on airflow distribution on the PCB with components treated with liquid crystal to visualize the temperature distributions on the PCB

About the Speaker

Kaveh Azar, Ph.D.

Dr. Kaveh Azar is the President and CEO of Advanced Thermal Solutions, Inc. (ATS), a leading edge thermal management company involved in developing liquid and air cooling solutions for the telecomm and computing market sectors. Under Dr. Azar's leadership, ATS has expanded globally with offices in Europe and Asia, and has become the leading supplier of cooling solutions and thermal management consulting to the telecomm market sector. Prior to ATS, Dr. Azar was the founder and manager of Lucent Technologies thermal management center, responsible for developing the next generation of cooling systems. In addition, Dr. Azar has authored Lucent's thermal roadmap and served as the corporate thermal consultant. While at Lucent, he developed a state-of-the- art thermal/fluids laboratory for simulation of components, boards and systems. Since 1985, Dr. Azar has been an active participant in electronics thermal community and has served as the organizer, general chair and the keynote speaker at the national and international conferences sponsored by ASME, IEEE and AIAA. He has also been an invitee to national bodies such as NSF, NIST and NEMI for organizing government and industry research goals in electronics cooling. Dr. Azar has been an adjunct professor at a number of universities in the USA, and lecturers worldwide on different facets of electronics cooling. He holds more than 31 national and international patents, has published more than 73 articles, 3 book chapters and a book entitled, "Thermal Measurements in Electronics Cooling" and has edited a 5 book series, "Qpedia – Electronics Thermal Management." In addition, he served as the Editor-in-Chief of Electronics Cooling Magazine for eleven years, and is currently the publisher of Qpedia, a monthly publication dedicated to thermal management of electronic systems. Dr. Azar has received several recognitions within Bell Labs and other entities that include Bell Labs' President Silver Award, Strathmore's Who's Who, The Uptime Institute for Visionary Leadership and IEEE SEMITHERM Significant Contributor Award in thermal management of electronics systems.

coolingZONE Short Courses

August 28, 2012 | Cambridge, MA

Short Course Agenda

The short courses run from 8:00 a.m. to 5:30 p.m. and includes a continental breakfast, lunch, and afternoon refreshments. Attendees will select one course per session. The short courses offered are as follows:

Transitioning From Air to Liquid Cooled: Design of Heat Exchangers and Cold Plates
Alfonso Ortega, Ph.D.
Thermal Design of Electronic Systems for Use in Data Centers
Chris Aldham, Ph.D.
Advanced Thermal Management Materials
Carl Zweben, Ph.D.
Simulating Natural Convection-Cooled Systems in CFD
Ruben Bons
Thermal Characterization and Measurement of LEDs
Norbert Engelberts

Goal

To provide the participants with the best practice of thermal measurement in electronics application and provide a hands-on experience on these best practices.

Who Should Attend?

Managers and engineer's engaged in the design of electronic systems which require measurement for design verification and subsequent product release.

How to Register

The cost to attend the day-long short course program on August 28, 2012 is $695.00, with a discounted rate of $795.00 if registered by July 31, 2012. Space is limited and advanced registration is required.

To register for the short courses, please visit www.coolingzone.com
For more information, please contact 508-329-2021 or registration@coolingzone.com

Morning Sessions (4 hours)

Attendees will select ONE of the following short courses to attend from 8:00am to 12:15pm. There will be a 15 minutes break at 10am. These include:

Transitioning From Air to Liquid Cooled: Design of Heat Exchangers and Cold Plates

Alfonso Ortega, Ph.D.
Associate Dean for Graduate Studies and Research
James R. Birle Professor of Energy Technology
College of Engineering, Villanova University

8:00am-12:15pm

Abstract Coming Soon

Thermal Design of Electronic Systems for Use in Data Centers

Chris Aldham, Ph.D.
Product Manager, 6SigmaET, Future Facilities

8:00am-12:15pm

The need for thermal design of electronic systems is well understood and many engineers are employed to estimate heat transfer characteristic, simulate using CFD and measure prototypes to ensure optimum thermal performance. Thermal design is now being carried out upfront and not just at the end of the design process as an afterthought. However, much of this thermal design work is done with only scant regard for the actual operating environment for the system. Often vague guidelines, like 10-35^{o}C (50-95^{o}F), will be used to specify the inlet air temperature and the system will be verified to work in these conditions Within data centers huge amounts of money are spent to ensure a cool environment for the electronics they house. But thermal problems in data centers are far more common than would be expected considering the effort (and money) expended. Why is this? This half-day course will introduce some typical data center cooling scenarios and the guidelines and metrics used to describe the performance. It will discuss the thermal design of electronic systems with specific emphasis on the interaction between the system and its environment.

Afternoon Sessions (4 hours)

Attendees will select from the following short courses to attend from 1:15pm to 5:30pm. There will be a 15 minutes break at 3:15pm. These include:

Advanced Thermal Management Materials

Carl Zweben, Ph.D.
Advanced Thermal Materials Consultant **1:15pm-5:30pm**

The need for advanced thermal management and packaging materials is highlighted in many roadmaps. In response, there have been revolutionary advances in the last few years. There are now many low-CTE, lightweight materials with thermal conductivities up to 1700 W/m-K (over 4X copper). Advanced materials can reduce component and system cost. They can tailor PCB CTE, potentially eliminating the need for underfill. They also can increase PCB thermal conductivity. Some manufacturers have replaced copper with Al/SiC in IGBT modules, which has "eliminated solder joint failure", increasing lifetime from 10 to 30 years. There are a large and increasing number of microelectronic and photonic applications, including: substrates; PCBs; PCB cold plates; heat spreaders; heat sinks; microprocessor, RF and power packages; thermoelectric cooler heat sinks; laser diode and LED packages; displays; photovoltaic packaging; detectors; and enclosures. This course covers the large and increasing number of high-performance thermal management materials, including properties, manufacturing processes, applications, cost, lessons learned, typical development programs, and future directions, including carbon nanotubes and graphene and the potential for greatly improved thermal interface materials. The course also discusses traditional thermal management materials, of which many

Simulating Natural Convection-Cooled Systems in CFD

Ruben Bons
Electronics Sector Manager, CD-Adapco **1:15pm-3:15pm**

Natural convection is the preferred method of cooling for many electronic systems, including LEDs, due to the inherent simplicity, reliability, size, weight, and power requirement advantages over forced air cooling. Design of natural convection-cooled systems can benefit enormously from the insight provided by flow and thermal simulation, especially when the sensitivity to various design variables is investigated. This short course will examine the approach to simulating natural convection-cooled systems in a CFD program. Particular physical phenomena, their impact on the simulation process, and focused guidelines will be addressed. Specific topics include: the setup of natural convection simulations ; most efficient modeling of small sealed air pockets; and radiation effects on the thermal performance. The background theory, simulation details, and design implications of each topic will be presented.

Thermal Characterization and Measurement of LEDs

Norbert Engelberts
Director, ATS-Europe, BV **3:30pm-5:30pm**

The need for thermal design of electronic systems is well understood and many engineers are employed to estimate heat transfer characteristic, simulate using CFD and measure prototypes to ensure optimum thermal performance. Thermal design is now being carried out upfront and not just at the end of the design process as an afterthought. However, much of this thermal design work is done with only scant regard for the actual operating environment for the system. Often vague guidelines, like 10-35°C (50-95°F), will be used to specify the inlet air temperature and the system will be verified to work in these conditions Within data centers huge amounts of money are spent to ensure a cool environment for the electronics they house. But thermal problems in data centers are far more common than would be expected considering the effort (and money) expended. Why is this? This half-day course will introduce some typical data center cooling scenarios and the guidelines and metrics used to describe the performance. It will discuss the thermal design of electronic systems with specific emphasis on the interaction between the system and its environment.

About the Speakers

Chris Aldham, Ph.D.

Dr. Chris Aldham has worked in computational fluid dynamics (CFD) for over 30 years (starting with PHOENICS at CHAM with Prof. Brian Spalding) and for more than 20 years in the field of electronics cooling. After 16 years at Flomerics, Chris joined Future Facilities as a Product Manager responsible for 6SigmaET – electronics cooling simulation software which is part of a suite of integrated software products that tackle head-on the challenges of data center lifecycle engineering (including equipment design analysis) through the Virtual Facility.

Ruben Bons

Ruben Bons is the Electronics Sector Manager with CD-adapco, responsible for understanding and addressing the market needs of electronics thermal management applications with STAR-CCM+. He joined CD-adapco about 1 year ago after previously working for Structural Research & Analysis Corporation and Blue Ridge Numerics. Ruben has spent more than 15 years using, supporting, and selling a wide range of simulation programs including structural, thermal, flow, kinematic, and electromagnetic analyses. For the past 8 years most of his work has focused on the application of CFD to electronics thermal management. Ruben Bons is based in southern California in the United States.

Norbert P. Engeleberts

Norbert P. Engelberts is the director of Advanced Thermal Solutions Europe and has been actively involved in electronics cooling since 1992. Prior to ATS, Engelberts headed the Thermal Design and Environmental Testing Group for Bell Labs, Lucent Technologies (now Alcatel-Lucent). During his 11 year tenure at Bell Labs, he was responsible for the thermal management and environmental testing (indoor and outdoor) of all telecommunications system equipment developed by the company in the Netherlands. In addition, Engelberts also brings with him expertise in HVAC system design, particularly those that house telecommunications and networking equipment. He works as a senior consultant for marked leading companies in the area of semiconductor, telecom, military, automotive and lighting. He has an extensive experience in the thermal management of LED based lighting solutions for a variety of applications, including automotive, street lighting, led replacement lamps.

Alfonso Ortega, Ph.D.

Dr. Alfonso Ortega is the James R. Birle Professor of Energy Technology at Villanova University and Associate Dean for Graduate Studies and Research for the College of Engineering. He received his B.S. in 1976 from The University of Texas-El Paso, and his M.S. and Ph.D. from Stanford University in 1978 and 1986 respectively, all in Mechanical Engineering. He was on the faculty of Aerospace and Mechanical engineering at The University of Arizona from 1988 to 2005 where he founded and directed the Experimental and Computational Heat Transfer Laboratory. From 2004 to 2006, Dr. Ortega was the Program Director for Thermal Transport and Thermal Processing in the Chemical and Transport Systems Division of The National Science Foundation in Arlington, Virginia. He joined the faculty of Mechanical Engineering at Villanova University in 2005. Dr. Ortega directs the Laboratory for Advanced Thermal and Fluid Systems conducting research in the heat transfer and fluid mechanics fundamentals of convective heat transfer in single and two phase flow, especially in problems that arise from the technology of electronics thermal management, gas turbine cooling, and alternative energy technologies. He has supervised nearly 40 M.S. and Ph.D. candidates to degree completion and is the author of over 300 journal and symposia papers. Dr. Ortega is a Fellow of the ASME and is currently Associate Editor of the ASME Journal of Heat Transfer.

Carl Zweben, Ph.D.

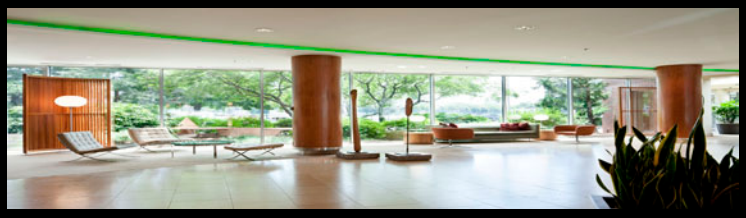
Dr. Zweben, now an independent consultant, has directed development and application of advanced electronic packaging and thermal management materials for over 35 years. His group at GE was the first to use Al/SiC (silicon-carbide-particle-reinforced aluminum) and other advanced materials in electronics and photonics. He was formerly Advanced Technology Manager and Division Fellow at GE Astro Space, where he directed the Composites Center of Excellence. Other affiliations have included Du Pont, Jet Propulsion Laboratory and the Georgia Tech National Science Foundation Packaging Research Center. Dr. Zweben was the first, and one of only two winners of both the GE One-in-a-Thousand and Engineer-of-the-Year awards. He is a Life Fellow of ASME, a Fellow of ASM and SAMPE, an Associate Fellow of AIAA, and has been a Distinguished Lecturer for AIAA and ASME. He has published and lectured widely on advanced thermal management materials, and is co-editor-in-chief of the six-volume Comprehensive Composite Materials. Dr. Zweben's clients have included numerous government agencies and major corporations, including Nokia, Delphi Electronics, Coherent Laser, Lumileds, Beacon Power, Themis Computer, Boeing, Hughes, ITT, General Dynamics, Northrop Grumman Laser Systems, COM DEV, GE Advanced Materials, GrafTech, Advanced Diamond, BP-Amoco, Ciba-Geigy, k-Technology, Zyvex Corporation, Poco Graphite, Princeton University High Energy Physics Group, and many others. He has taught over 250 short courses in the US, Europe and Asia. He also has been an expert witness for Seoul Semiconductor and other organizations.

Hotel and Area Information

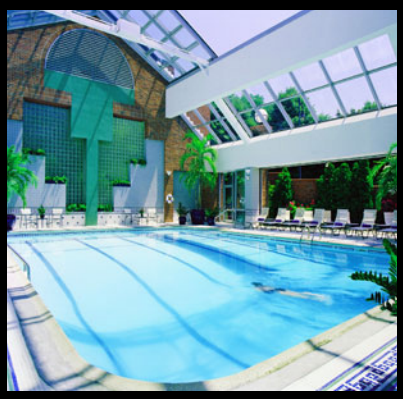
The Royal Sonesta Hotel

40 Edwin Land Boulevard
Cambridge, MA 02142
617-806-4200
www.sonesta.com

The 12th International Conference and Exhibition will be held at the Royal Sonesta Hotel in Cambridge, MA located on the banks of the scenic Charles River. Offering views of the Boston skyline and less than one mile from MIT, Harvard University, high-tech, bio-tech and financial centers of both Cambridge and Boston, the Royal Sonesta Hotel affords a perfect venue for coolingZONE Summit attendees to participate in our industry-leading conference and network with academic and industry leaders in the area.



Above: Hotel Lobby
Below: Art Bar (Left) , Pool & Spa (Right)



A special room rate of $199 per night is offered for attendees. Reserve your preferred accommodation by:

1) Reserving on-line at www.coolingzone.com. Go to EVENTS and select the REGISTRATION tab. Select the HOTELS AND AREA INFORMATION tab and link directly to the hotel URL dedicated for coolingZONE, LLC with discounted room rates.

2) Calling the Hotel directly at 617-806-4200 and asking for Reservations. Reference coolingZONE to receive your discounted room rate; or

3) Email the Hotel directly at reservations@sonesta-boston.com. Reference coolingZONE to receive your discounted room rate.

Note: standard room rate without the discount during this time period is $279 per night. Rooms reserved at the special rate of $199 are limited, so call today to reserve your room and enjoy all the benefits Royal Sonesta, Cambridge and Boston have to offer!

Transportation

Airport Transfers and Parking

Logan International Airport is just 3 miles from the Royal Sonesta Hotel. Taxi Service is available to and from Logan Airport. Travel from Logan Airport to the Royal Sonesta Hotel is provided by Boston taxi companies. Fares are a metered rate and can range from $25 to $30 depending upon traffic conditions and the time of arrival. Return travel from the Royal Sonesta back to Logan Airport is provided by Cambridge taxi companies. Fares are flat rates, inclusive of all tolls, taxes and driver gratuities.

Hotel Courtesy Vans

Daily routes provide scheduled stop to MIT, Kendall Square, Quincy Market/Faneuil Hall Marketplace and the Prudential Center/Copley. Shuttle service is FREE to all registered guests of the Royal Sonesta Hotel, however reservations are required. Please contact Guest Services at 617-806-4250 to receive a current schedule of departure and arrival times available and confirm your reservation. NOTE: Shuttle service is not available to Logan International Airport (3 miles away), however, taxis are available on-site for your convenience.

Public Transportation

Logan International Airport is accessible by subway using the Green MBTA line (0.7 miles from Airport): Take the Green Line MBTA trolley/bus to Lechmere Station. Exit and follow signs to Cambridge Street. Cross to First Street and walk along the CambridgeSide Galleria to Charles Street/CambridgeSide Place. Turn left and the Hotel will be at the end of the block.

Garage Parking

Guest Services can reserve a vehicle from any of the major car rental companies.

Directions

From the Logan International Airport:

Take the main airport roadway (one-way) out of the airport and follow signs for "Route 1A / Sumner Tunnel, Boston/ I 93" Enter the tunnel and stay in the right lane. As you exit the Summer Tunnel, veer right into the tunnel for Storrow Drive. As you exit this tunnel, make a left following signs for "Leverett Circle / North Station.' At the second light, make a left and follow 28 North (McGrath / O'Brien highway). You will pass the Museum of Science on your left. After two traffic lights, turn left onto Edwin H. Land Boulevard (sign will say Memorial Drive) follow to first traffic light and turn left into the Royal Sonesta's driveway.

From the North (Route 93S):

Take Route 93 South to Exit 26 (not accessible from carpool lane), "Storrow Drive/Cambridge/Route 28N/ Route 3N." Stay to the right, moving to the middle lane, following signs for "Route 28 North/Cambridge/ North Station." At the traffic signal, turn left onto Nashua Street. Take the first right onto Route 28 North/Msgr O'Brien Highway. Pass the Museum of Science on your left. Proceed to the second traffic light and turn left onto Edwin Land Boulevard. The hotel is on the left at the next traffic signal, across from the CambridgeSide Galleria.

From the South (Route 93N):

Take Route 93 North to the Liberty Tunnel (move to the right lane after Exit 23). Take Exit 26, "Storrow Drive". Stay to the right moving onto Storrow Drive. Take immediate left exit "Government Center/Kendall Square" and turn right at the top of the ramp, onto the Longfellow Bridge. Proceed to the traffic signal and turn right onto Third Street. Proceed to the traffic signal and turn right onto Binney Street and proceed to the end. At the traffic signal, turn left onto Edwin Land Boulevard. The hotel entrance and garage are located on the right at the next traffic signal, across from the CambridgeSide Galleria.

From the Massachusetts Turnpike:

Take exit 18, Allston/Cambridge (left exit) Bear Right, after toll booth bear right towards Cambridge. Go straight through 3 sets of lights (this will bring you on to River Street). Continue straight down River Street until you come to Massachusetts Avenue (approx. .6 mile) get into right lane to turn on Mass. Ave. Go straight down Massachusetts Ave for .2 mile and turn/bear left onto Main Street (not clearly marked). Continue on Main Street .4 Mile through 3 sets of lights and turn left onto Galileo Way and take it all the way to the end. Turn left onto Edwin Land Blvd, getting in the right lane, The Royal Sonesta will be on the right at the next light

Cambridge, MA

Stroll the cobble-stone streets of Cambridge where world-class educational institutions coexist with our nation's history. Packed with an international flair and youthful vitality, Boston is a leader for economic, political, and social change. Home to Harvard and MIT, Cambridge is a heady mix of students, scholars, and visitors from around the world. It's a cosmopolitan college town with an eclectic array of bookstores, coffee houses, blues clubs, street musicians, repertory theaters, and mouthwatering ethnic restaurants. With a picturesque riverfront and breathtaking skyline, you will soon discover why the charm of the Charles River is contagious. Boston and Cambridge are a perfect blend of stylish sophistication and historic New England charm.

Harvard

Take a stroll through the ivy-covered Harvard Yard and see the famous "Statue of Three Lies", and you will walk the same path as some of the greatest minds in history. Curl up with a book at the world-famous Harvard COOP Bookstore or grab something to eat at any of the hip, ethnic restaurants of Harvard Square.

Harvard University / The Harvard Coop Bookstore
1400 Massachusetts Avenue
18 Palmer Street | Cambridge, MA 02238
617.499.2800 | www.harvardcoopbooks.com
Open Mon - Sat 9am – 9pm | Sun 10am - 7pm

MIT

The MIT Museum invites you to explore invention, ideas, and innovation. Through interactive exhibitions, public programs, experimental projects and its renown collections, the MIT Museum showcases the fascinating world of MIT, and inspires people of all ages about the possibilities and opportunities offered by science and technology.

Massachusetts Institute of Technology/ MIT Museum
Building N51 | 265 Massachusetts Avenue | Cambridge, MA 02139
617.253.5927 | www.mit.edu
Open Daily 10am – 5pm

Museum of Science

The Museum of Science, located 100 yards from the hotel, has remained on the cutting edge of science education by developing over 400 innovative and interactive exhibits and programs that both entertain and educate. In addition to the exhibits, there is the Mugar Omni Theater, the Charles Hayden Planetarium and the Butterfly Garden.

Science Park | Boston, MA 02114
617.723.2500 | www.mos.org
Open Sat - Thurs 9am – 5pm | Friday 9am - 9pm

Museum of Fine Arts

The Museum of Fine Arts is one of the most comprehensive art museums in the world with nearly 450,000 works of art. Each year, more than one million visitors experience the museum's spectacular exhibits, from ancient Egyptian to contemporary works, as well as special exhibitions and innovative educational programs.

465 Huntington Avenue | Boston, MA 02115
617.267.9300 | www.mfa.org
Open Mon & Tues 10 am - 4:45 pm | Wed - Fri 10am - 9:45pm
Sat & Sun 10 am - 4:45pm

New England Aquarium

The New England Aquarium is home to the 200,000-gallon tank known as the Caribbean Coral Reef Exhibit. The reef accommodates not only sharks, sea turtles, barracuda and moray, but also hundreds of smaller exotic tropical fish, and it is one of the most detailed and scientifically accurate presentations of its kind.

Central Wharf | Boston, MA 02110
617.973.5200 | www.neaq.org
Open Mon - Fri 9am – 5pm | Sat & Sun 9am - 6pm

Boston Duck Tours

You haven't toured Boston until you've taken a Boston Duck Tour! The fun begins as soon as you board your "DUCK", an authentic, renovated World War II amphibious landing vehicle. View all the historic landmarks in a way you've never experienced and take a cruise through the city streets and harbor.

Tours depart from the Museum of Science
Science Park | Boston, MA 02114
617.267.DUCK| www.bostonducktours.com

Boston Common

Stroll through the infamous Boston Common, America's first park, and the Public Garden, its first public botanical garden. Admire the rich and unusual plants, the Lagoon, monuments and fountain. Take a graceful ride on the Swan boats and enjoy the natural beauty of its 24 acres.

Boston Public Garden
Arlington Street | Boston, MA 02130
www.swanboats.com

Fanuiel Hall

Faneuil Hall, often referred to as the "Cradle of Liberty," comes alive as festive street performers wow you with magic, acrobatics, music, and dancing. Shop for one-of-a-kind gifts and specialty items. Dine at 5-star restaurants, historic Irish pubs, or Cheers "where everyone know you're name." In addition, you'll find over 36 international food vendors inside of the Quincy Market Colonnade, the largest food hall in New England. Whatever you're looking for, Fanuiel Hall has it all.

Fanuiel Hall Marketplace
State Street | Boston, MA 02130
www.faneuilhallmarketplace.com

Fenway Park

Visit one of America's most beloved ballpark, home to the 2004 and 2007 World Champion Boston Red Sox. Take a tour of Fenway as it celebrates its 100th year to soak up baseball history, hear echoes of the past, and touch the Green Monster of this iconic ballpark. Not just for the sports fan, Lansdowne street is a popular local and tourist attraction for fun restaurants and night life.

4 Yawkey Way | Boston, MA 02215
617.226.6666 | www.redsox.com

Additional Highlights:

- Newbury Street shops and restaurants
- Boston's North End famous Italian restaurants
- Wilbur, Colonial, and Wang theater performances
- Freedom Trail walking tours
- Samuel Adams and Harpoon breweries
- Boating on the Charles River

International Business and Technology Summit

Thermal Management of Electronics

Emerging Technologies for Advanced Cooling of Electronic Systems

coolingZONE

August 27-30, 2012 | Cambridge, MA

Registration Information

Register online at www.coolingzone.com through our secure online processing

Summit	**Before July 31, 2012** **After July 31, 2012** Includes: Conference Proceedings, Breakfast and Lunch each day, Exhibit Hall admission and Networking Reception.	**$995 per person** **$1395 per person**
Pre-Summit Short Course	**Before July 31, 2012** **After July 31, 2012** Includes: Lecture Notes, Breakfast and Lunch. Discounted day parking rate at the hotel is applicable for short course participants.	**$695 per person** **$795 per person**
coolingZONE Short Courses	**Before July 31, 2012** **After July 31, 2012** Includes: Lecture Notes, Breakfast and Lunch. Discounted day parking rate at the hotel is applicable for short course participants.	**$695 per person** **$795 per person**
Package A: Pre-Summit Short Course and coolingZONE Short Courses	**Before July 31, 2012** **After July 31, 2012** Includes: Lecture Notes, Breakfast and Lunch. Discounted day parking rate at the hotel is applicable for short course participants.	**$1390 per person** **$1590 per person**
Package B: Summit and Pre-Summit Short Course	**Before July 31, 2012** **After July 31, 2012** Includes: Lecture Notes, Conference Proceedings, Breakfast and Lunch each day, Exhibit Hall admission and Networking Reception.	**$1495 per person** **$1995 per person**
Package C: Summit and coolingZONE Short Courses	**Before July 31, 2012** **After July 31, 2012** Includes: Lecture Notes, Conference Proceedings, Breakfast and Lunch each day, Exhibit Hall admission and Networking Reception.	**$1495 per person** **$1995 per person**
Package D: Full Program	**Before July 31, 2012** **After July 31, 2012** Includes: Lecture Notes, Conference Proceedings, Breakfast and Lunch each day, Exhibit Hall admission and Networking Reception.	**$1995 per person** **$2595 per person**

No refund is provided for cancellation. However, you may transfer your registration to another person to attend in your place.

Questions? Contact coolingZONE at 508-329-2021 or registration@coolingzone.com

International Business and Technology Summit

Thermal Management of Electronics

Emerging Technologies for Advanced Cooling of Electronic Systems

August 27-30, 2012 | Cambridge, MA

Registration Form

Pre-Summit Short Course: August, 27, 2012 8:00am – 5:30pm
coolingZONE Short Courses: August 28, 2012 8:00am – 5:30pm
Summit: August 29-30, 2012 7:30am – 5:00pm
Networking Reception: August 29, 2012 5:00pm – 7:00pm

INFORMATION:

First Name:	Last Name:	Title:
Company:	Address:	
City:	State:	Postal Code:
Country	Phone:	Fax:
Email:	Signature:	Date:

SELECTION:

Please select the event(s) that you are registering for from the options below

❒ **Summit**	**Before July 31, 2012** **After July 31, 2012**	**$995 per person** **$1395 per person**
❒ **Pre-Summit Short Course**	**Before July 31, 2012** **After July 31, 2012**	**$695 per person** **$795 per person**
❒ **coolingZONE Short Courses**	**Before July 31, 2012** **After July 31, 2012**	**$695 per person** **$795 per person**
❒ **Package A:** **Pre-Summit Short Course & coolingZONE Short Courses**	**Before July 31, 2012** **After July 31, 2012**	**$1390 per person** **$1590 per person**
❒ **Package B:** **Summit & Pre-Summit Short Course**	**Before July 31, 2012** **After July 31, 2012**	**$1495 per person** **$1995 per person**
❒ **Package C:** **Summit & coolingZONE Short Courses**	**Before July 31, 2012** **After July 31, 2012**	**$1495 per person** **$1995 per person**
❒ **Package D:** **Full Program**	**Before July 31, 2012** **After July 31, 2012**	**$1995 per person** **$2595 per person**

PAYMENT INFORMATION:

Payment Type (select one): ❒ **Check** ❒ **Credit Card (MC/Visa/AmEx/Discover)**

Credit Card #: _____ Cardholder's Name: _____

Expiration Date: _____ Cardholder's Signature: _____

Billing Address: _____ Billing Phone: _____

Make check payable to: coolingZONE, LLC. Mail payment to: coolingZONE, LLC 859 Willard St.,STE 400, Quincy, MA 02169

Email form to registration@coolingZONE.com

Contact Us

For personalized assistance with questions or registration, please contact us at 508-329-2021 or email coolingZONE, LLC at:

Registration: registration@coolingzone.com
Exhibit/Sponsorship: registration@coolingzone.com
Program Information: cz-info@coolingzone.com

coolingZONE

International Business and Technology Summit

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August 27-30, 2012 | Cambridge, MA