



## SEMI-THERM 36 SHORT COURSES

Monday March 16, 2020

### 8:00 a.m. Short Course 1: **Introduction to Electronics Cooling**

Patrick Loney, Northrop Grumman Mission Systems

As electronic packages get smaller and the power dissipations increase, performing robust thermal analyses is an increasingly important step in the electronics packaging design process. This course will focus on the component level of the electronics assembly. Thermal management, proper cooling techniques, component attachment, and analytical modeling methods will be presented. How to decipher vendor datasheets will be discussed as well as the basics of how to model custom components. Best practices for steady state and transient operational modes are included. Process development will also be presented along with discussions on requirements compliance. Students will finish the course with an understanding of how to determine the limits and requirements of an electronics component, assess the thermal performance, how to integrate the performance model into a Next Higher Assembly (NHA) thermal model, and most importantly, how to communicate this information to their internal and external customers who are dependent on this data.

### 8:00 a.m. Short Course 2: **Introduction to Thermal Modeling with OpenFOAM**

John F. Maddox, University of Kentucky

OpenFOAM is the leading free, open source software for computational fluid dynamics (CFD). This course is an introduction to thermal modeling using OpenFOAM for users familiar with CFD and heat transfer, however, no prior experience with OpenFOAM is required. Attendees will be introduced to the OpenFOAM environment through hands-on tutorials covering meshing, solving, and post-processing with a focus on conjugate heat transfer. Attendees wishing to participate in the hand-on tutorials will need to bring a laptop with a 64-bit operating system (Window, Mac, or Linux) and Oracle VM VirtualBox installed. All the software required for this course will be free and open source.



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### 8:00 a.m. Short Course 3: **Design and Optimization of Heat Sinks**

Marc Hodes and Georgios Karamanis, Transport Phenomena Technologies, LLC

This course provides the audience with an understanding of heat sink design and optimization in the context of the thermal management of electronics. The course has two parts. The first part begins with an overview of common methods to manufacture heat sinks such as extrusion, die casting and forging, and discusses their advantages and disadvantages with respect to cost and fin geometry. Attention then shifts to the theory of spreading resistance and how it can be calculated in order to properly size the thicknesses of the bases of heat sinks. Next, the theory of the operation of heat pipes in tubular and flat (vapor chamber) configurations is presented along with their roles in smoothing out temperature gradients in the fins and bases of heat sinks. In the second part of the course, single-phase conjugate heat transfer, where conduction in the heat sink is coupled to convection in the coolant, i.e., air or water, flowing through the heat sink is highlighted. We discuss why the constant heat transfer coefficient assumption tends to be an invalid one in real heat sinks by using specific examples. Then, the use of computational fluid dynamics (CFD) to compute conjugate Nusselt numbers is considered. The course concludes with a discussion of how to embed pre-computed results for conjugate Nusselt numbers and dimensionless flow resistances for heat sinks in flow network models (FNMs) of circuit packs such as blade servers. Finally, how to use a multi-variable optimization scheme to optimize the geometry (fin thickness, spacing, height, length, say) of an array of heat sinks in a circuit pack represented by an FNM model with embedded tabulations of CFD results is discussed.

### 1:30 p.m. Short Course 4 **Air Movers and Aeroacoustics for Electronics Cooling**

Mark MacDonald, Intel Corporation

This course will survey performance characteristics of various relevant fan types, including axial fans, blowers, crossflow or tangential blowers, volumetric resistance blowers, and other emerging technologies including electronhydrodynamic blowers, synthetic jets, piezo flappers, and micropumps. Emphasis will be placed on understanding the physical mechanisms of operation, best practices for characterization, implementation considerations, and applicable scaling laws (including acoustic scaling laws). The course will also cover aeroacoustics and psychoacoustics (sound quality and ergonomics) for consumer electronics in detail.



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### 1:30 p.m. Short Course 5 **Micro-Two-Phase Electronics Cooling...Getting it on its Way**

John R. Thome, EPFL

Two-phase flow and flow boiling heat transfer can reliably cool heat fluxes in excess of 500 W/cm<sup>2</sup> with heat transfer coefficients nearing 100 kW/m<sup>2</sup>K with respect to the cold plate's base area. Yet, industry is hesitant to accept this technology on a large scale. Most of the reservations about this approach are easily mitigated with proper design/planning, and the benefits are substantial. In general, a micro-thermosyphon that works passively with gravity-driven flow is used with heat dissipation to a compact air coil. Due to the new "form factor" and huge surface area of the coil compared to an air-cooled heat sink, energy consumption by the fans is greatly reduced. Furthermore, a thermosyphon (no electrical driver or flow controllers) provides high reliability that is commonplace with packages which use two-phase thermal management. This lecture will recount the history and background of two-phase cooling, noting lessons learned along the way. Several case studies will be presented where a design flaw was mitigated and the resulting improvements in performance will be highlighted. At the end of this course, you will be able to successfully design a two-phase cold plate cooled system which improves the reliability, cost of operation, and longevity of your devices.

### 1:30 p.m. Short Course 6 **Let's Work Together: How Co-Design Leads to Better Solutions in Thermal Management**

Lauren Boteler, Army Research

Laboratory Optimization studies are generally done intradisciplinary rather than interdisciplinary, and this leads to conflict as different fields have different values when it comes to what they want in a packaged solution. Heat sinks in energy dense power electronics are an excellent example of where better communication and co-design models can yield significant improvements to fielded performance with just a small amount of preparation during the design phase. Parameterization and Figure of Merit (FOM) definitions that encapsulate electrical/ thermal/mechanical properties pare down the solution space to a set that represents what all fields want rather than cyclically proposing "optimal" solutions that one or more fields can't possibly accommodate. This course will examine how fielded solutions were truly optimized using novel co-design tools and optimization techniques which span multiple disciplines. The case studies examined will show marked improvement beyond what single-track minded approaches yield, and lessons learned from this course will translate directly to better solutions in your workplace.