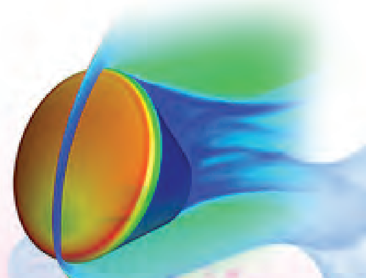
National Aeronautics and Space Administration

# 27th Annual Thermal and Fluids Analysis Workshop (TFAWS)

**August 1 – 4, 2016**

## Workshop Features

**Paper Sessions**
**Software and Hardware Demonstrations**
**Hands-on Software Training**
**Technical Short Courses**
**Guest Speakers**
**Tour of Ames Research Center**



NASA Ames Research Center Moffett Field, CA

# Overview:

The Thermal and Fluids Analysis WorkShop (TFAWS) is an annual NASA-sponsored training and professional development workshop to advances the science and technology for thermal and fluid physics analysis. It's purpose is to encourage knowledge sharing, professional development, and networking throughout the thermal and fluids engineering community as well as the aerospace community at large. To this end, it offers activities that accommodates engineers at all levels of experience including new hires and students. The vision of TFAWS is to maintain continuity across time, and centers as well as between disciplines (passive thermal, active thermal, aero-thermal, etc). Annual sharing of knowledge allows engineers to be current with lessons learned. The inter-center nature of the conference helps ensure knowledge sharing across the agency. It also helps minimize overlaps and duplications across centers. TFAWS provides a tremendous opportunity for enhancing collaboration between NASA centers, with other government agencies, industry, academia, and international thermal and fluids science community. TFAWS is planned by a cross-agency steering committee and the hosting duties rotate to a different center each year. Ames Research Center is proud to be hosting TFAWS 2016.

This year, the conference will be held at the NASA Ames conference center in Building 152 on Moffett Field from Aug. 1 – 4, 2016. TFAWS 2016 consists of four parallel sessions for training and one session for paper presentations. Of the four training sessions, two are hands-on software training provided by various commercial software vendors. One session is dedicated to theoretical course presentations, and the final session consists of software demonstrations and group meetings.

The paper presentation session provides the opportunity for those in the thermal-fluids community to present their work to their peers. This allows for greater dissemination of this material within the community as well as provides a valuable forum for discussion about its applicability to other advancements within the various disciplines. The paper session is split into five categories based on the general focus for each topic area: Active Thermal, Passive Thermal, Heat Pipes, Aero-thermal, and Interdisciplinary.

Plenary talks will be presented at lunchtime along with a keynote talk at the banquet.

Finally, hardware and software vendors will provide information to the attendees at tables/booths.

# TFAWS Agenda 2016

**Monday**

<table>
<tr><th>Room</th><th>103/104</th><th>105/106</th><th>114</th><th>117</th><th>120</th><th>171</th><th>ARC Center tours</th></tr>
<tr><td>8-9</td><td rowspan="4">Introduction to C&R Thermal Desktop and FlowCAD: Douglas Bell</td><td rowspan="4">Introduction to TSS</td><td rowspan="2">Hypersonic ground testing: Karen Berger</td><td colspan="4" rowspan="4"></td></tr>
<tr><td>9-10</td></tr>
<tr><td>10-11</td><td rowspan="2">Thermal testing: Eric Grob</td></tr>
<tr><td>11-12</td></tr>
<tr><td>12-12:10</td><td colspan="5"></td><td>ARC Center director: Eugene Tu</td></tr>
<tr><td>12:10-12:25</td><td colspan="5"></td><td>Pick up lunch</td></tr>
<tr><td>12:25-1</td><td colspan="5"></td><td>Lunchtime talk: A Mechanically Deployable Entry System Development for Human Mars and Robotic Science Missions: Raj Venkatapathy</td></tr>
<tr><td>1-2</td><td rowspan="4">Introduction to RadCAD: Douglas Bell</td><td rowspan="4">Introduction to TSS</td><td rowspan="4">CBAero: David Kinney</td><td rowspan="4">Interdisciplinary Paper Session 1</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>2-3</td></tr>
<tr><td>3-4</td><td rowspan="2">TFAWS Delegates Meeting</td><td rowspan="2"></td></tr>
<tr><td>4-5</td></tr>
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**Tuesday**

<table>
<tr><th>Room</th><th>103/104</th><th>105/106</th><th>114</th><th>117</th><th>120</th><th>171</th></tr>
<tr><td>8-9</td><td rowspan="4">COMSOL Multiphysics for Thermal and Fluids Analysis</td><td rowspan="4">Advanced TSS</td><td></td><td></td><td rowspan="2">CR Tech software demo</td><td rowspan="4"></td></tr>
<tr><td>9-10</td><td>NEQAIR v14.0 User Tutorial: Aaron Brandis</td><td rowspan="3">Heat Pipes Session</td></tr>
<tr><td>10-11</td><td rowspan="2">An Introduction to the Data-Parallel Line Relaxation (DPLR) Software Package: Chun Tang</td><td>ESATAN-TMS demo</td></tr>
<tr><td>11-12</td><td></td></tr>
<tr><td>12-12:25</td><td colspan="5"></td><td>Pick up lunch</td></tr>
<tr><td>12:25-1</td><td colspan="5"></td><td>Lunchtime talk: A Pathway to Innovation: Dan Rasky</td></tr>
<tr><td>1-2</td><td rowspan="4">Introduction to C&R TD Direct: Douglas Bell</td><td rowspan="4">Advanced TSS</td><td rowspan="4"></td><td rowspan="4">Passive Thermal Paper Session 1</td><td>Space Design demo</td><td rowspan="4"></td></tr>
<tr><td>2-3</td><td>MSC Software demo</td></tr>
<tr><td>3-4</td><td>Mentor graphics Demo: CAD-Embedded CFD</td></tr>
<tr><td>4-5</td><td>Mentor graphics Demo: Electronics, Cooling, …</td></tr>
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**Wednesday**

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<tr><td>8-9</td><td rowspan="4">MSC Apex</td><td rowspan="4">Thermal Analysis Results Processor</td><td></td><td></td><td colspan="2" rowspan="2"></td></tr>
<tr><td>9-10</td><td rowspan="3">Modeling Mistakes: Ruth Amundsen</td><td rowspan="3">Interdisciplinary Paper Session 2</td></tr>
<tr><td>10-11</td><td rowspan="2">Active TDT face-to-face Meeting (NASA-only)</td><td rowspan="2"></td></tr>
<tr><td>11-12</td></tr>
<tr><td>12-12:25</td><td colspan="5"></td><td>Pick up lunch</td></tr>
<tr><td>12:25-1</td><td colspan="5"></td><td>Lunchtime talk: Orion Exploration Flight Test One (EFT-1) Spacecraft Recovery and Thermal Protection System (TPS) Assessment: Jeremy van der Kam</td></tr>
<tr><td>1-2</td><td rowspan="4">Mentor Graphics-CAD Embedded CFD</td><td rowspan="4">COVeR: Caprture Output and Verify Results</td><td rowspan="2">Lithium-Ion Batteries: William Walker</td><td rowspan="4">Active Thermal Paper Session 1</td><td rowspan="4">Passive TDT face-to-face Meeting (By invitation-only)</td><td rowspan="4"></td></tr>
<tr><td>2-3</td></tr>
<tr><td>3-4</td><td>Siemens PLM NX Thermal, Flow, and Spapce Systems Thermal software demo</td></tr>
<tr><td>4-5</td><td></td></tr>
<tr><td>6-8</td><td colspan="6">Banquet @ Michael's Restaurant at Shoreline: Gregory Zilliac : Parafin Rockets</td></tr>
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**Thursday**

<table>
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<tr><td>8-9</td><td></td><td rowspan="2">Siemens PLM NX Spapce Systems Termal</td><td rowspan="4">Intro. To Numerical Methods in Heat Transfer: Steve Rickman</td><td></td><td colspan="2" rowspan="4"></td><td></td></tr>
<tr><td>9-10</td><td rowspan="3">ESATAN-TMS</td><td rowspan="3">Active Thermal Paper Session 2</td><td></td></tr>
<tr><td>10-11</td><td rowspan="2">Siemens PLM FEMAP Advanced Thermal</td><td rowspan="3">Future Flight Central and Pleiades Supercomputer Tour</td></tr>
<tr><td>11-12</td></tr>
<tr><td>12-12:25</td><td colspan="5"></td><td>Pick up lunch</td></tr>
<tr><td>12:25-1</td><td colspan="5"></td><td>Lunchtime talk: Hydrocode Modeling of Asteroid Entry, Airburst, and Impacts for Hazard Assessment: Darrel Robertson</td><td></td></tr>
<tr><td>1-2</td><td rowspan="3">ESATAN-TMS</td><td rowspan="4">Introduction to GFSSP</td><td rowspan="4">Boiling and Condensation: Henry Nahra</td><td rowspan="2">Thermoanalytics demo</td><td rowspan="2">ITAR Paper Session U.S. Persons Only</td><td rowspan="4"></td><td></td></tr>
<tr><td>2-3</td><td></td></tr>
<tr><td>3-4</td><td rowspan="2">COMSOL demo</td><td rowspan="2"></td><td></td></tr>
<tr><td>4-5</td><td></td><td></td></tr>
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# Paper Sessions:

All paper sessions are in room 117 except ITAR session is in room 120.
The following papers will be presented in the paper sessions. Please see https://www.tfaws.nasa.gov for individual paper abstracts.

| Paper ID | Time | Author(s) | Title |
|---|---|---|---|
| **Monday, August 1, 2016** | | | |
| TFAWS2016-I-10 | 1:30pm | Heather Bradshaw | Thermal Design, TVAC Testing, and Lessons Learned for Critical GSE of ATLAS and the ICESat-2 Mission |
| TFAWS2016-I-12 | 2:00pm | Srujan K. Rokkam, John W. Lawson , Peter Cross, and Richard Burns | Computational Tools for Modeling Chemical Degradation in Extreme Environments |
| TFAWS2016-I-13 | 2:30pm | Srujan K. Rokkam and Max D. Gunzburger | Computational Tools for Modeling Chemical Degradation in Extreme Environments |
| TFAWS2016-I-14 | 3:00pm | Dr. Ted Wertheimer and Dr. Hendrik Schafstall | Manufacturing Simulation Incorporating Phase Transformations |
| TFAWS2016-I-15 | 3:30pm | Sandeep Yayathi, William Walker, Daniel Doughty, and Haleh Ardebili | New Understanding of Energy Distributions Exhibited during Thermal Runaway of Commercial Lithium Ion Batteries used for Human Spaceflight Applications |
| TFAWS2016-I-16 | 4:00pm | Rebecca Stavely | Review of Lessons Learned from RaD-X High Altitude Balloon Flight in September 2015 |
| **Tuesday, August 2, 2016** | | | |
| TFAWS2016-HP-01 | 9:00am | Jentung Ku, Triem Hoang | Recent Developments of the Cryogenic Loop Heat Pipe Technology |
| TFAWS2016-HP-02 | 9:30am | Mohammed T. Ababneh, Calin Tarau, William G. Anderson, Jeffery T. Farmer, Angel R. Alvarez-Hernandez | Hybrid Variable Conductance Heat Pipe and HiK™ Plates – Advanced Passive Thermal Experiment |
| TFAWS2016-HP-03 | 10:00am | William G. Anderson, Mohammed T. Ababneh, Derek Beard, and Calin Tarau | High Temperature Water-Titanium Heat Pipe Radiators for the Kilopower Fission Power System |
| TFAWS2016-HP-04 | 10:30am | Derek Beard, Calin Tarau and William G. Anderson | Alkali Metal Heat Pipes for the Kilopower Nuclear Reactor |
| TFAWS2016-HP-05 | 11:00am | Calin Tarau, Taylor Maxwell, William G. Anderson, Corey Wagner, Matthew Wrosch, Maxwell H. Briggs | Development of a Low-Cost Water Heat Pipe Radiator for Fission Surface Power |
| TFAWS2016-HP-07 | 11:30am | Evan Shea | Thermal Modeling and Test Correlation for SWOT Loop Heat Pipe |

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|---|---|---|---|
| TFAWS2016-PT-01 | 1:00pm | Matt Flannery, James Schmidt, Jens Weyant, Kevin Thorson | Thermally Enhanced Card Retainers for Aerospace Electronics Systems |
| TFAWS2016-PT-02 | 1:30pm | William G. Anderson, Pete Ritt, Calin Tarau, Jens Weyant | Applications for Phase Change Material (PCM) Heat Sinks |
| TFAWS2016-PT-03 | 2:00pm | Eugene K. Ungar, Sarah E. Wright | Temporary Thermocouple Attachment for Thermal/Vacuum Testing at Non-Extreme Temperatures |
| TFAWS2016-PT-04 | 2:30pm | Jorge J. Garza | Lithium-Ion Thermal Management System: Thermal Analysis for Safe Battery Pack Design |
| TFAWS2016-PT-06 | 3:00pm | Matthew Redmond | Thermal Conductance across Ball Bearings in Vacuum |
| TFAWS2016-PT-08 | 3:30pm | Xiao-Yen Wang and William Fabanich | Advanced Features of Thermal Desktop®/SINDA-FLUINT: Interface with Matlab and Using SpaceClaim For Complex Geometries |
| TFAWS2016-PT-09 | 4:00pm | Robert J. Cochran | TNSolver: An Open Source Thermal Network Solver for Octave or MATLAB |
| TFAWS2016-PT-10 | 4:30pm | Pooja S. Desai | Cryogenic Tank Pressurization and Liquefaction System Modeling in Thermal Desktop |
| **Wednesday, August 3, 2016** | | | |
| TFAWS2016-I-01 | 9:00am | Sahadeo Ramjatan and Alvin Yew | Hydrodynamic Pressure Generated in Lubricant Film around Low-Friction Shaftless Reaction Wheel |
| TFAWS2016-I-02 | 9:30am | Arundhuti Banerjee, Tanusree Chakraborty, and Vasant Matsagar | Application of Active Heat Exchanger Systems for Energy Extraction from Oceanic Crust |
| TFAWS2016-I-04 | 10:00am | Matt Garrison, Deepak Patel, Heather Bradshaw, Frank Robinson, and Dave Neuberger | Lessons Learned on the Advanced Topographic Laser Altimeter System |
| TFAWS2016-I-05 | 10:30am | Derek Hengeveld | Reduced-Order Modeling for Rapid Thermal Analysis and Evaluation of Spacecraft |
| TFAWS2016-I-06 | 11:00am | Brent Cullimore, Doug Bell | Modeling the World's Worst Performing Yet Most Popular Heat Engine |
| TFAWS2016-I-07 | 11:30pm | Douglas P. Bell and Tim Panczak | Verification of Curved Elements for Thermal Analysis |
| TFAWS2016-AT-15 | 1:00pm | Alex Scammell and Jungho Kim | The effect of Gravity on Single Vapor Elongated Bubbles |
| TFAWS2016-AT-01 | 1:30pm | Andre LeClair and Alok Majumdar | Thermo-Fluid Modeling of the Pressurization and Draining of a 1000 Gallon Cryogenic Tank with GFSSP |
| TFAWS2016-AT-02 | 2:00pm | Darnell Cowan | Coolant Refill of the Photovoltaic Thermal Control System on the International Space Station |

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|---|---|---|---|
| TFAWS2016-AT-03 | 2:30pm | Eric Lira | Modeling the Rapid Boil-off of a Cryogenic Liquid When Injected into a Low Pressure Cavity |
| TFAWS2016-AT-04 | 3:00pm | Kenichi Sakamoto, Takurou Daimaru, Hiroki Nagai, Stefano Cappucci, Pradeep Bhandari, Benjamin Furst, Eric Sunada | System Trade-off Analysis of Two-Phase Mechanically Pumped Fluid Loop for Thermal Control of Future Deep Space Missions |
| TFAWS2016-AT-05<br>TFAWS2016-AT-08 | 3:30pm<br><br>4:00pm | Michael C. Ellis, Richard C. Kurwitz<br>Ryan Gilligan, Thomas Tomsik | Development of a Pumped Two-Phase System for Spacecraft Thermal Control<br>Using 1D thermodynamic and Heat Transfer Equations to quickly and Accurately Model Tank Pressurization |
| TFAWS2016-AT-12 | 4:30pm | Lauren M. Best Ameen, Joseph G. Zoeckler | Subscale Investigation of Vapor Cooling Enhancements for Applications on Large In-space Cryogenic Vehicles |
| **Thursday, August 4, 2016** | | | |
| TFAWS2016-AT-09 | 9:00am | A. J. Mastropietro, Pradeep Bhandari, Gaj Birur, Hared Ochoa, Jenny Hua, Anthony Paris, Nick Emis, Dave Bame, Ray Higuera, Yuanming Liu, Paul Karlmann, Gordon Cucullu, Jackie Lyra, Keith Novak, Jen Miller, Jason Kempenaar, Matthew Redmond, Eddie Farias, Brian Carroll, Josh Kempenaar, and Daniel Zayas | Summary and Status of 5 Mechanical Pumped Fluid Loop (MPFL) Projects Currently in Process at the Jet Propulsion Laboratory (JPL) for the Planned Europa Mission, MARS 2020, Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), Orbiting Carbon Observatory (OCO-3) and Cold Atom Lab (CAL) |
| TFAWS2016-AT-10 | 9:30am | Christopher Evans | CFD Flow Analysis and Resizing Studies for the Evaporator of the ISS Urine Processor Assembly |
| TFAWS2016-AT-11 | 10:00am | Bruce Conger, Janice V. Makinen | Proof of Concept for Novel High Performance Torso Cooling Garment |
| | 10:30am | | |
| TFAWS2016-AT-13 | 11:00am | Daniel Bacellar, Vikrant Aute, Zhiwei Huang, Reinhard Radermacher | Design of High Performance Gas-to-Fluid Heat Exchangers using Shape and Topology Optimization |
| TFAWS2016-AT-14 | 11:30am | Xiao-Yen Wang and David Plachta | Modeling of Gaseous Oxygen Liquefaction Inside Mars Ascent Vehicle Propellant Tank |
| TFAWS2016-AE-02 | 1:30pm | Anthony Iannetti<br>Room 120 | A System Level CFD Effluent Analysis of a Small-Cell Lithium Ion Battery Thermal Runaway Process for the Multi-Purpose Crew Vehicle (Orion) |

## Short Courses:

### Aerothermal Ground Testing: How, Where and Why?
### Monday, August 1, 8:00am – 10:00am, Room 114
### Instructor: Karen Berger, NASA Langley Research Center

*Karen Berger is the Facility Manager for the Langley Aerothermodynamics Laboratory at NASA Langley Research Center. She started at NASA as a co-op student in 2003, joined the Aerothermodynamics Branch in 2005 as a researcher and transferred to the facility manager role in 2014. She got her BS and MS in Aerospace Engineering from Virginia Tech in 2005 and 2009 respectively.*

This course will include an overview of the major hypersonic ground test facilities around the country and their capabilities. Test techniques and instrumentation available to researchers will be covered as well. A summary of a number of major ground testing and flight programs over the years will be covered and will highlight the significant contributions obtained through ground testing. This will include blunt, slender and winged configurations.

### Spacecraft Thermal Vacuum Test – A Point in Time
### Monday, August 1, 10:00am – 12:00pm, Room 114
### Instructor: Eric Grob, NASA Goddard Space Flight Center

*After initially working for the US Navy as a test engineer, Mr. Grob's career in heat transfer began with U.S. Navy radar electronics packaging at RCA, then with satellites at General Electric and Lockheed-Martin where he helped develop the thermal control for several commercial and civil space satellites. Since coming to Goddard Space Flight Center in 1999, Mr. Grob has led the thermal design for several missions, including the Geoscience Laser Altimeter System (GLAS launched 2003) that pioneered the use of propylene loop heat pipes for thermal control in NASA missions. Following this, he was project manager for a solar observing instrument before returning to the GSFC thermal engineering branch as Chief Engineer where he conducts peer reviews and supports mission review panels for numerous GSFC projects, and also provides thermal support for various projects – currently the Geostationary Operational Environmental Satellite (GOES-R) program.*

*Mr. Grob received his BSME degree from West Virginia University in 1980 and his MSME from Drexel University in 1989.*

Spacecraft thermal vacuum testing is the most complicated and longest duration environmental test. This course will look at a specific case – thermal vacuum testing of the first in the latest series of NOAA weather satellites, the Geostationary Operational Environmental Satellite System – that spanned almost two months and was completed late last summer. Based on a heritage satellite bus (the 43rd), and employing watrod to simulate environmental heating, the test design, completion, and post-test analysis is covered in detail, concluding with some remarkable lessons learned.

## Common Thermal Modeling Mistakes
### Wednesday, August 3, 9:00am – 12:00pm, Room 114
### Instructor: Ruth Amundsen, NASA Langley Research Center

*Ms. Amundsen has a BS in Physics from Stanford University, and dual master's in materials science and aerospace engineering from University of Michigan. She started in aerospace work at Martin Marietta, and has been at NASA Langley since 1990 doing thermal design and engineering for spacecraft and launch vehicles.*

This course will cover the some of the common mistakes made in thermal modeling, and how to avoid them. Thermal Desktop will be used as a platform to demonstrate many of the common errors by both new analysts as well as experienced engineers in building a thermal model. Other non-software-associated errors will also be covered. Topics covered will include common errors in assumptions, materials, configurations, radiation, orbital analysis, and common faults in problem setup, analysis case runs and record-keeping. The course should help you as an engineer to watch for these common errors in the future, and help you avoid them.

**Short Course on Lithium-on Batteries: Fundamental Concepts, Heating Mechanisms and Simulation Techniques**
**Wednesday, August 3, 1:00pm – 3:00pm, Room 114**
**Instructor: William Walker, NASA Johnson Space Center**

*Mr. Walker graduated from West Texas A&M University with a B.S. in Mechanical Engineering and began his career with Johnson Space Center (JSC) after the spring 2012 semester. He is currently a Ph.D. candidate in Materials Science and Engineering at the University of Houston with a research focus on thermo-electrochemical testing and analysis of lithium-ion (Li-ion) battery assemblies designed for human spaceflight applications. W. Walker is the recipient of a 2015-2016 JSC Academic Fellowship for which he is conducting Li-ion battery thermal runaway research. W. Walker has been involved in the development and design efforts for the Orion battery assembly and the Robonaut 2 battery "backpack." In addition, W. Walker is working with the NASA Engineering and Safety Center (NESC) to characterize the thermal runaway energy release distributions of various commercial Li-ion cells via accelerating rate calorimetry (ARC).*

This short course provides participants with an in-depth discussion on three aspects of lithium-ion (Li-ion) batteries that are relevant to the TFAWS community. First an understanding of Li-ion battery fundamentals is provided through a brief discussion centered around (a) the aerospace industry's choice to use Li-ion batteries, (b) general performance characteristics and (c) electrochemical reaction basics. Secondly, Li-ion battery heat generation is discussed with respect to (a) Ohmic heating that occurs during nominal charge-discharge operations and (b) the heating mechanisms associated with a thermal runaway event. Understanding both heating mechanisms is critical to the development of effective thermal management systems. Lastly, this course will lead the participants through the basic construction process of a thermal model of a Li-ion battery assembly that is capable of simulating nominal heating and thermal runaway heating. The overall goal of the course is to provide participants with an in-depth understanding of both the fundamental and thermal aspects of Li-ion batteries.

**Introduction to Numerical Methods in Heat Transfer**
**Thursday, August 4, 8:00am – 12:00pm, Room 114**
**Instructor: Steve Rickman, NASA Engineering and Safety Center**

*Steve Rickman joined the NASA Engineering and Safety Center in January 2009 as the NASA Technical Fellow for Passive Thermal. In this capacity, he leads a cross-agency Technical Discipline Team, leveraging expertise from within and outside of the Agency to solve high risk technical problems and foster a community of practice for the passive thermal control and thermal protection disciplines. His primary interest has been in the area of passive thermal control of orbiting spacecraft. He has authored or co-authored 15 technical papers and conference presentations including public testimony given with the U.S. Air Force to the Columbia Accident Investigation Board. He authored a textbook chapter on natural and induced thermal environments. He holds a U.S. patent as a co-inventor of an innovative space station concept. Steve has received numerous mentoring, Group Achievement, Tech Brief and Space Act Awards and has been honored with the NASA Exceptional Achievement Medal and the Silver Snoopy. In autumn 2011, he was named an Adjunct Professor/Lecturer of Mechanical Engineering at Rice University. Mr. Rickman received a B.S. in Aerospace Engineering from the University of Cincinnati and earned his M.S. in Physical Science from the University of Houston-Clear Lake.*

This course provides an overview and introduction to numerical methods in heat transfer. The Heat Equation, the governing differential equation, is derived from first principles and solved for an example problem. The finite difference method is derived from the governing differential equation and applied in example problems including the effects of radiation, steady state and transient response. Numerical solution accuracy and the concept of the time constant are discussed. The Calculus of Variations is applied to derive the Euler-Lagrange equation leading to a formulation of the finite element method and applied to a variety of examples. This course is an excellent introduction for those engineers early in their career in thermal analysis or seeking information in this field and a review for experienced analysts.

**Two Phase Flow, Boiling and Condensation**
**Thursday, August 4, 1:00pm – 5:00pm, Room 114**
**Instructor: Dr. Henry Nahra, NASA Glenn Research Center**

*Dr. Nahra is the Flow Boiling and Condensation Experiment fluid systems project lead engineer. He holds a Ph.D. in Mechanical and Aerospace Engineering-Fluid and Thermal Sciences, a Master degree in Physics from Case Western Reserve University, and a Master and a Bachelor degree in Chemical Engineering from Cleveland State University. Dr. Nahra served as the project scientist for various flight and ground microgravity experiment including critical point phenomena and bubble suspension flight experiments. Dr. Nahra's research interests are in the areas of Bubble flows, Bubble Formation and Detachment and Hydrodynamic Forces on Bubbles. Dr. Nahra is an AIAA Associate Fellow since 2003. Dr. Nahra is an adjunct faculty in the mechanical engineering department at Cleveland State University.*

This short course provides the basics of two phase flow hydrodynamics and heat transfer. Physical parameters of practical interest used in the analysis of two-phase flows will be discussed. In specific, methods for computing pressure drop and heat transfer coefficients in two phase flows will be presented. Solution methods will be elaborated and applied to specific cases of engineering applications pertaining to boiling and condensation. Moreover, a treatment of the boiling heat transfer and the critical heat flux, including the effects of microgravity will be presented in this short course.

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## Hands-on Training:

**Introduction to C&R Thermal Desktop® and FloCAD®**
**Monday, August 1, 8:00am – 12:00pm, Room 103/104**

Instructor: Douglas Bell

This session will provide an introduction to the capabilities of Thermal Desktop and FloCAD through the creation of simple models that include radiation and fluid flow. Thermal Desktop is a pre- and postprocessor for SINDA; FloCAD adds fluid model development based on thermal model geometry and flow path centerlines. No previous experience with Thermal Desktop is expected. Experienced users are welcome but are requested to allow new users to have priority at the workstations.

Mr. Bell has been involved in heat transfer and fluid flow since 1993 and has been using C&R Thermal Desktop since 2000. With a BS degree in Aerospace Engineering from North Carolina State University, Mr. Bell has worked for NASA, Lockheed Martin and CRTech. Mr. Bell has performed thermal or fluid analyses on: stratospheric airships and research balloons and their flight control electronics; the thermal protection systems of X-33 and hypersonic vehicles; launch control electronics for missile launchers; missile storage containers and launch tubes; boilers; and on-orbit spacecraft.

**Introduction to RadCAD®**
**Monday, August 1, 1:00pm – 5:00pm, Room 103/104**

Instructor: Douglas Bell

This session will provide an introduction to the capabilities of RadCAD through the creation of simple radiation models. RadCAD performs surface-to-surface radiation exchange calculations and environmental heating calculations. No previous experience with Thermal Desktop is expected. Experienced users are welcome but are requested to allow new users to have priority at the workstations.

**Introduction to TSS and v15.01**
**Monday, August 1, 8:00am – 5:00pm, Room 105/106**

Instructors: Joe Lepore, Joe Clay

This hands-on class will progress through a thermal analysis of a spacecraft using version v15.01. The student will go through each major step in the analysis process using a simple example. This is the basic framework needed to create, analyze, and obtain temperatures using TSS. The spacecraft model will begin as a CAD file, which is moved into TSS by using the Transfer application. As each TSS application is used, user interface and TSS features are demonstrated by the instructor and utilized by the student. Calculations of radks, heating rates, conduction/capacitance network, and temperatures are performed. The latest TSS capabilities demonstrated in this class include the return of the Executive application for Windows and SindaWin application. Everyone interested in learning how to perform satellite thermal analysis should attend this class.

**COMSOL Multiphysics for Thermal and Fluid Analysis**
**Tuesday, August 2, 8:00am – 12:00pm, Room 103/104**

Instructor: John Dunec

John Dunec is COMSOL's VP of sales for the northwest US and regularly teaches training courses. He received his Ph.D. from Stanford and has spent over 20 years in the engineering industry. In 1998, John became COMSOL's first customer. In 2005, he joined COMSOL and opened the Palo Alto office.

Company Description: COMSOL Multiphysics® is an integrated software environment for creating physics-based models and simulation apps. A particular strength is its ability to account for coupled or multiphysics phenomena. Add-on products expand the simulation platform for electrical, mechanical, fluid flow, and chemical applications. Interfacing tools enable the integration of COMSOL Multiphysics® simulations with all major technical computing and CAD tools on the CAE market. Simulation experts rely on the COMSOL Server™ product to deploy apps to their design teams, manufacturing departments, test laboratories, and customers throughout the world.

**Introduction to CRTech TD Direct®**
**Tuesday, August 2, 1:00pm – 5:00pm, Room 103/104**

Instructor: Douglas Bell

This session will provide an introduction to the capabilities of CRTech TD Direct. TD Direct is powerful software that fills the gap between design geometry and C&R Thermal Desktop. TD Direct is built in ANSYS SpaceClaim, a CAD tool that focuses on preparing geometry for analysis, just as Thermal Desktop is built in AutoCAD. With TD Direct, the user is able to solve many of the problems that have challenged thermal engineers for years. The starting point is the full design geometry in any format. The final product is the completed analysis in Thermal Desktop. The step in between is TD Direct, where the user has the ability to easily simplify, heal, and alter the geometry while working with an exceedingly capable mesher.

**Advanced TSS**
**Tuesday, August 2, 8:00am – 5:00pm, Room 105/106**

Instructors: Joe Lepore, Joe Clay

This hands-on class will demonstrate more TSS features and modeling techniques. Topics will include: Radiation analysis of CAD surfaces using STEP and IGES Translators, SindaWin application and using LDDATA to automatically record local minimum and maximum temperatures, Geometry model validation, building models with Symbols, distributed processing, managing Boolean surfaces and chains, adjusting conductor values, using the Mesh and FEM applications, and SATSTRAN. Topics of specific interest to users and v15 enhancements will be discussed. Example topics include the rich feature set in TSS such as programming in the command language, utilizing TSS as a prototyping tool, eliminating costly 3rd party applications to move data from a CAD package to a thermal software system, and utilizing TSS as a simple CAD package.

The Transfer application is used to view CAD models and transfer them into TSS geometry format. Transfer has a 'CAD viewer' built-in, allowing you to view any CAD model saved in IGES, STEP, or OBJ format. This viewer shows a meshed representation of the model which can then be transferred to TSS Geometry format in a single step. Using advanced 2-D and 3-D Boolean capabilities (computational geometry), complex CAD entities are converted into thermal surfaces using fewer surfaces for radiation analysis. Transfer methods available include direct conversion to files compatible with specific TSS versions, plus a 2-D mesh approximation using surfaces or boundary representation. This class will present a detailed walk-through of the Transfer process, including discussion of B-splines, sequence numbers, composite closed loops, and troubleshooting.

**MSC Apex – CAE Specific direct modeling and meshing solution that streamlines CAD clean-up, simplification and meshing workflow for 10 X productivity gain.**
**Wednesday, August 3, 8:00am – 12:00pm, Room 103/104**

Instructor: Dr. Shekhar Kanetkar

MSC Apex is a new CAE platform developed by MSC that has won 13 major innovation awards including NASA Tech Brief 2014 – Product of the Year. It is an easy to learn and easy to use tool that give a use a 'unique and fun experience.' The demo will focus on use of Apex to achieve 10x productivity gain in CAD to mesh process. It will also showcase its fully integrated and its generative analysis solution as well as exciting technology of computational parts and assemblies.

Dr. Shekhar Kanetkar received his Ph.D. in Metallurgical Engineering from The University of Alabama in 1988. He has over 25 years of experience in doing Thermal Analysis with Phase transformations, Spacecraft Thermal Analysis and Nonlinear Structural analysis (FEA) for aerospace and automotive industry. In his role at MSC, he has been supporting customers including NASA KSC and MSFC for over 16 years.

**Mentor Graphics– CFD hands-on workshop for FloEFD, CAD Embedded CFD**
**Wednesday, August 3, 1:00pm – 5:00pm, Room 103/104**

Instructors: Chris Watson & Adrian Townsend

This hands-on workshop introduces FloEFD, CAD Embedded Computational Fluid Dynamics (CFD) Software and will include analysis of an internal flow component, an electronics cooling enclosure and one other example from model preparation, user interface, simulation set up, meshing and solution, to accessing results and running parametric studies. CAD-Embedded CFD possible with FloEFD for Siemens NX, PTC Creo, and CATIA V5 and a stand-alone version feature robust automated meshing, faster time to analysis using CAD geometry directly within the CAD interface, guided simulation set up and straight forward results post-processing. The rapid parametric studies capability for refining geometry or accessing a wide variety of operational conditions will also be introduced.

Chris is the Technical Manager for FloEFD Products for the Mechanical Analysis Division of Mentor Graphics. He is responsible for technical leadership of Mentor's FloEFD product line in North America. His engineering roles through the years have included consulting, technical support, customer training, and pre and post sales application engineering. Currently he works in the software development group to help influence the direction of FloEFD and promote its growth in North America.

Prior to Mentor Graphics, Chris worked for NIKA and CD-adapco, starting his career in the commercial CFD industry in 1995. Chris received his BS in Aerospace Engineering from the University of Texas at Austin, and his MS in Mechanical Engineering from Texas A&M University.

Adrian is an Applications Engineer for the Mechanical Analysis Division of Mentor Graphics. Based in Fremont, California his role involves sales support and consulting and workflow improvement services throughout the Bay Area and western U.S. region. His expertise includes the FloTHERM, FloEFD and FloTHERM XT CFD tools as well as the T3Ster hardware suite. Adrian's work with Mentor Graphics spans a broad range of applications including consumer electronics design, thermal testing of semiconductors for power-conversion, building ventilation, datacenter thermal analysis, external aerodynamics and turbo-machinery.

Before joining Mentor Graphics, Adrian was an Energy Efficiency Consultant with a focus on industrial plant retro-commissioning and capital investment and an Aerodynamicist with Boeing commercial New Airplane Product Development. He received a BS in Aeronautics and Astronautics from MIT and an MS in Applied Mathematics from the University of Washington.

Mentor Graphics –Mechanical Analysis Division provides 3D Fully CAD Embedded CFD fluid dynamics software (FloEFD™ for Siemens NX, CATIA and PTC CREO) and 1D thermo-fluid computational fluid dynamics software (Flowmaster®) for shortened development in Aerospace, Defense and other Industries/Applications ranging from external flow analysis to internal flow systems and component level analysis. Mentor Graphics also provides electronics cooling specific simulation software (FloTHERM®) and MicReD semiconductor thermal test solutions used for failure diagnosis, reliability studies (combined with power cycling) and thermal characterization (T3Ster® & Power Tester Product Range). MicReD® thermal transient test solutions provide accurate, repeatable thermal characterization of LEDs, packaged ICs to TIM materials, to simulation model calibration and right through to power electronics reliability studies through failure in progress diagnosis combined with active power cycling. www.mentor.com/mechanical

**Thermal Analysis Results Processor (TARP)/ COVeR: Capture Output and Verify Results**
**Wednesday, August 3, 8:00am – 5:00pm, Room 105/106**

Instructor: Hume Peabody

The first half of the course will introduce the basic object types in TARP, including: DataSets, Groups, Parameters, Plots, Tables, and HeatMaps. More advanced data objects will also be discussed including: Backloads/Equivalent Sinks, Graphical Tables, Radk Compares and Manipulations, and Binary Heat Maps. The second half of the course will focus on the COVeR environment, including: Data Selection, Groups, Plotting, and Graphical HeatMaps, which are a block diagram way of visualizing heat flow data from model output.

Thermal Modeling Solutions was founded in 2005 by Hume Peabody. The first product TARP (Thermal Analysis Results Processor) was a dedicated post processing environment for interfacing with Microsoft Excel and standard output files from many commercial thermal solvers. Future releases featured additional capabilities for visualizing data and addressing ever growing model sizes. More recently, the COVeR (Capture Output and Verify Results) tool was released, which provides a self contained environment for the processing of model output, with a specific focus on heat flows. The underlying philosophy in both TARP and COVeR is two-fold: be able to read output from many commercial, network based tools and nodal level results can be grouped to represent physical components of a design. While models may be growing in size, the fundamental behavior of heat flow between components of a design remains unaffected by model size.

**ESATAN-TMS Software Training**
**Thursday, August 4, 9:00am – 5:00pm, Room 103/104**

Instructor: Nicolas Bures

ITP will be providing hands-on training of ESATAN Thermal Modelling Suite (ESATAN-TMS) at TFAWS 2016. This hands-on training will allow the attendees to gain knowledge and valuable experience of ESATAN-TMS. The training will cover geometry definition and modification of an existing model within ESATAN-TMS Workbench. Through ESATAN-TMS Workbench, the design of a satellite test model will be finalised, radiative analysis performed to calculate heat fluxes and radiative exchange factors. Both steady state and transient thermal analysis will be performed, followed by postprocessing of the results using the extensive capabilities provided within ESATAN-TMS. Design consideration will be given to material selection and other key parameters to achieve the desired thermal requirements. This hands-on training will be an easy step-by-step workflow, with two ESATAN-TMS experts on hand to provide an effective training experience.

Mr. Bures is the support engineer for ESATAN-TMS, as well as the thermal software engineer at ITP Engines UK LTD.

**Siemens PLM NX Space Systems Thermal**
**Thursday, August 4, 8:00am – 10:00am, Room 105/106**

Instructor: Carl Poplawsky

This is an open-door session to try out Siemens PLM NX Space Systems Thermal, the NX space industry vertical application that provides a comprehensive set of tools to simulate orbital thermal analysis within the NX Advanced Simulation environment. Carl Poplawsky will provide a brief introduction to the NX user interface, followed by a self-paced workshop that takes the user through working with large assemblies while leveraging existing simulation models, defining thermal conductances and orbital heating, implementing articulation of spacecraft components, controlling the simulation with a spreadsheet, and addressing free molecular heating.

Carl Poplawsky is a senior applications engineer with Maya Simulation Technologies, a Siemens PLM value added reseller (VAR), software development partner, and engineering services provider. We are one of the leading VARs in North America, with a focus on CAE software products, offering sales, technical support, training, and custom software development for Siemens PLM NX and Femap. As a software development partner, Maya provides software for the Siemens PLM NX and Femap-based CAE product sets, including NX Thermal, NX Flow, and NX Space Systems Thermal (formerly I-deas TMG). Maya develops and markets additional software tools, including Datacenter Clarity (3D tool set for managing data center infrastructure) and delivers engineering services to clients worldwide, with a focus on CAE-based thermal, flow, and structural analysis.

**Siemens PLM FEMAP Advanced Thermal**
**Thursday, August 4, 10:00am – 12:00pm, Room 105/106**

Instructor: Carl Poplawsky

This is an open-door session to try out Siemens PLM Femap Advanced Thermal. Femap Thermal adds state-of-the-art thermal analysis solutions to the Femap environment and provides fast and accurate solutions to complex thermal engineering problems, making it easy to model nonlinear and transient heat transfer processes including conduction, radiation, 1D fluid network modeling, and free and forced convection. Femap Advanced Thermal adds an extensive suite of thermal modeling tools for more sophisticated thermal simulations, such as radiation and spacecraft modeling, (including solar and orbital heating), orbit modeling and display, ray tracing capabilities, and articulating structures. Carl Poplawsky will provide a brief introduction to the Femap user interface, followed by a self-paced workshop that takes the user through a typical spacecraft thermal simulation. For those of you unable to attend the 8AM NX Space Systems Thermal session, that workshop will also be available during this session.

**Introduction to Generalized Fluid System Simulation Program (GFSSP)**
**Thursday, August 4, 1:00pm – 5:00pm, Room 105/106**

Instructor: Andre LeClair

GFSSP is a general-purpose computer program for analyzing steady-state and time-dependent flow rates, pressures, temperatures, and concentrations in a complex flow network. The program is capable of modeling phase change, compressibility, mixture thermodynamics, conjugate heat transfer, and fluid transient (waterhammer). GFSSP was been developed at MSFC for flow analysis of rocket engine turbopumps and propulsion systems. This demonstration will show how to the user can quickly develop a system-level thermo-fluid model, discuss the capabilities of the software, and present model examples. Students will build two models as a group activity, and have the opportunity to work one or more hands-on tutorials.

Andre LeClair is a propulsion thermal analyst at NASA's Marshall Space Flight Center. He assists in GFSSP development and user support. His modeling activities include chilldown of cryogenic transfer lines and pressurization of propellant tanks.

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## Software Demonstrations:

**CB Aero**
**Monday, August 1, 1:00pm – 5:00pm, Room 114**

Instructor: David Kinney

The Configuration Based Aerodynamics (CBAero) software package is an engineering level aero-thermodynamics tool used to predict aerodynamic and aero-thermal environments of vehicles. It is capable of predicting convective and radiative heating environments for re-entry vehicles such as the Orion Spacecraft in a variety of simulated flight conditions.

Dr. David Kinney received his Ph.D. from University of California at Davis. He is the primary developer of the CBAero code at NASA Ames Research Center.

**NEQAIR v14.0 User Tutorial**
**Tuesday, August 2, 8:00am – 10:00am, Room 114**

Instructor: Aaron Brandis

NEQAIR is a line-by-line radiation code that computes spontaneous emission, absorption and stimulated emission due to transitions between various energy states of chemical species along a line-of-sight. NEQAIR v14.0 is a complex code that enables the calculation of: (1) Nonequlibrium or equilibrium populations of excited energy levels for atomic and diatomic molecules, (2) Optical radiation emitted and absorbed by atomic and diatomic rotational lines along a line-of-sight or across a shock tube, (3)Transport of optical radiation through a non uniform gas mixture to a solid surface and (4) Detailed spectra at points along a line-of-sight and at a surface and plots them. Presentation to cover how to use and understand the NEQAIR code. The avenues to obtain the code will also be discussed.

Dr. Brandis received his undergraduate Bachelor of Engineering (Mechanical and Space) in 2003 and his Ph.D. at the University of Queensland and Ecole Central Paris in 2009. Dr Brandis is currently a research scientist employed by AMA Inc in the Thermodynamics branch at NASA Ames. He is the task lead for the model validation component of the Entry Systems Modeling project and PM/PI for NEQAIR, one of the agencies main radiation prediction tools.

**An Introduction to the Data-Parallel Line Relaxation (DPLR) Software Package**
**Tuesday, August 2, 10:00am – 12:00pm, Room 114**

Instructor: Chun Tang

This training course will provide an introduction to the DPLR software package, a suite of Computational Fluid Dynamics (CFD) tools developed at NASA Ames Research Center for aerothermal simulation of supersonic and hypersonic flows. The DPLR code is an MPI-based, parallel, three-dimensional Navier-Stokes solver with generalized models for thermal and chemical non-equilibrium. This software has been used extensively in atmospheric entry analysis for many projects (such as the Space Shuttle Program, Mars Science Laboratory, and Orion Multi-Purpose Crew Vehicle/Space Launch System). The course will outline a step-by-step process for running an aerothermal simulation, and examples on simple two-dimensional and three-dimensional shapes will be demonstrated.

Dr. Chun Tang is an aerospace engineer in the Aerothermodynamics Branch at NASA Ames Research Center. He received his B.S. degree in Mechanical and Aeronautical Engineering from the University of California, Davis. He also received his M.S. and Ph.D. degrees in Mechanical Engineering from UC Davis with a specialty in Computational Fluid Dynamics. Dr. Tang has worked on the Space Shuttle and Mars Science Laboratory Projects, and he is currently involved with the Mars 2020 and Orion MPCV Programs.

**New and Advanced Features in Thermal Desktop, Demo**
**Tuesday, August 2, 8:00am – 10:00am, Room 120**

Instructor: Douglas Bell

This session will provide an overview of new and advanced features within the Thermal Desktop suite and provide demonstration on the use of some of those features. This session is recommended to anyone who wishes to see more advanced capabilities of the Thermal Desktop suite than can be addressed in the introductory session. Since the session is not hands-on, prior experience with Thermal Desktop is not required. Thermal Desktop is a design environment for generating thermal models with additional modules for performing radiation and heating environment calculations (RadCAD) and generating fluid flow circuits (FloCAD). Thermal Desktop is a graphical user interface for SINDA/FLUINT.

**ESATAN-TMS Demo**
**Tuesday, August 2, 10:00am – 11:00am, Room 120**

Instructor: Nicolas Bures

ESATAN-TMS provides a complete environment to support the full thermal analysis process, including geometry modelling, radiative analysis, thermal-hydraulic analysis and post-processing of results. The high-productivity user interface supports a wide range of features which allow fast and accurate simulation, however complex the problem. ESATAN-TMS provides the ability to create thermal models comprising of 2D (shells) and/or 3D (solids) geometry, automatically identifying interfaces between the geometric primitives. The user can choose to perform the thermal analysis using either a lumped parameter or a finite element approach; or even a combination of both techniques within the same model, as best suited to the problem being solved.
The session shall start by providing an overview of the product's thermal modelling capabilities, followed by a live demonstration. The demonstration will show how easy a model can be created in ESATAN-TMS, with the option to import components of the model directly from CAD. A full radiative and thermal analysis will be performed, highlighting the major features of the product, concluding by post-processing of the thermal results. Further experience of ESATAN-TMS can be gained by attending the hands-on TFAWS session scheduled for Thursday, August 4.

**Space Design Demo**
**Tuesday, August 2, 1:00pm – 2:00pm, Room 120**

Instructor: Joe Clay

Timing studies which detail significant speed increases using v15.01B will be discussed. Newly released v15.01B highlights will be presented, including: Significant speed improvements over v14.01 for load times and ray-tracing, significant speed improvements to graphics rendering, multi-threaded processes for improved speed when running on both local and network drives, Transfer CAD models directly as thermal surfaces, improved Windows – Linux compatibility, including cross-platform database formats for Radk and Heatrate datasets, 4-Color display allows surface active side coloring to distinguish between active=both and active=up/down, optical property mapping in Geometry, multiple pages for Graphics Text, and listing areas in Radk by node, rather than by surface.

**MSC Apex – CAE Specific direct modeling and meshing solution that streamlines CAD clean-up, simplification and meshing workflow for 10 X productivity gain.**
**Tuesday, August 2, 2:00pm – 3:00pm, Room 120**

Instructor: Dr. Shekhar Kanetkar

MSC Apex is a new CAE platform developed by MSC that has won 13 major innovation awards including NASA tech Brief 2014 – Product of the Year. It is an easy to learn and easy to use tool that give a use a 'unique and fun experience'. The demo will focus on use of Apex to achieve 10x productivity gain in CAD to mesh process. It will also showcase its fully integrated and its generative analysis solution as well as exciting technology of computational parts and assemblies.

Dr. Shekhar Kanetkar received his Ph.D. in Metallurgical Engineering from The University of Alabama in 1988. He has over 25 years of experience in doing Thermal Analysis with Phase transformations, Spacecraft Thermal Analysis and Nonlinear Structural analysis (FEA) for aerospace and automotive industry. In his role at MSC, he has been supporting customers including NASA KSC and MSFC for over 16 years.

**Mentor Graphics Demo: CAD-Embedded CFD Technology**
**Tuesday, August 2, 3:00pm – 4:00pm, Room 120**

Instructor: Chris Watson, Product Development Manager

A technical overview of fully CAD-Embedded CFD possible with FloEFD for PTC Creo, Siemens NX and CATIA V5. The presentation includes discussion of working directly with CAD geometry in the CAD environment for fluid dynamics studies, robust automated meshing and refinement, guided simulation set up and accessing results through to extensive parametric studies for CAD geometry refinement or assessing operational scenarios. Live demonstration will include an external aerodynamics model and an internal flow system component analysis. A brief series of case studies on different applications will be included.

**Mentor Graphics Demo: Electronics, Cooling**
**Tuesday, August 2, 4:00pm – 5:00pm, Room 120**

Instructor: Adrian Townsend, Applications Engineer

In this presentation, the use of semiconductor thermal transient measurement results and automated calibration of detailed component thermal models in electronics cooling analysis is evaluated. The methodology and technology will be explained and then additionally the presentation will introduce how more accurate component thermal models help with defining mission profile based temperature cycle profiles which can be used to enhance power cycling and failure diagnosis studies on high power semiconductors in target applications.

**Siemens PLM NX Thermal, Flow, and Space Systems**
**Wednesday, August 3, 3:00pm – 4:00pm, Room 114**

Instructor: Carl Poplawsky

Siemens PLM NX Thermal, Flow, and Space Systems Thermal will be demonstrated by Carl Poplawsky with Maya Simulation Technologies. These add-on software modules provide heat transfer and fluid flow solutions when used with NX Advanced Simulation. NX Thermal simulates conduction, convection and radiation phenomena and NX Flow provides sophisticated tools to simulate fluid flow for complex parts and assemblies; when used concurrently they provide a fully coupled multi-physics solution. NX Space Systems Thermal is the NX space industry vertical application that provides a comprehensive set of tools to simulate orbital thermal analysis within the NX Advanced Simulation environment.

Carl Poplawsky is a senior applications engineer with Maya Simulation Technologies, a Siemens PLM value added reseller (VAR), software development partner, and engineering services provider. We are one of the leading VARs in North America, with a focus on CAE software products, offering sales, technical support, training, and custom software development for Siemens PLM NX and Femap. As a software development partner, Maya provides software for the Siemens PLM NX and Femap-based CAE product sets, including NX Thermal, NX Flow, and NX Space Systems Thermal (formerly I-deas TMG). Maya develops and markets additional software tools, including Datacenter Clarity (3D tool set for managing data center infrastructure) and delivers engineering services to clients worldwide, with a focus on CAE-based thermal, flow, and structural analysis.

**ThermoAnalytics Human Thermal Modeling Tutorial and Software Demo**
**Thursday, August 4, 1:00pm – 3:00pm, Room 117**

Instructor: Al Curran

ThermoAnalytics' Human Thermal Module (HTM) is an advanced, off-the-shelf thermo-physiological model that plugs into the powerful heat transfer simulation software, TAITherm. The HTM simulates the process by which the body attempts to maintain a constant core temperature. Numerous commercial and government entities use ThermoAnalytics' HTM. For example, NIOSH uses the HTM to predict skin and core temperatures as well as evaporation rates of mine shelter occupants. Additionally, MIT has used the TAITherm HTM to model its mechanical counter pressure (MCP) suit.
In this session, we describe state-of-the-art "segmental" human thermal models and demonstrate the capabilities of the TAITherm Human Thermal Module.

Dr. Curran is the Chief Technical Officer and co-founder of ThermoAnalytics, Inc. Dr. Curran's current research focuses on the development of human thermal physiology and comfort models. His previous research formed the basis of Ford Motor Company's thermal radiation analysis software, RadTherm, which evolved to become TAITherm. TAITherm is a general-purpose thermal simulation environment, which is in use worldwide, primarily in the automotive industry. Dr. Curran received his BS and MS in Mechanical Engineering from Northwestern University and his Ph.D. in Mechanical Engineering from Stanford University.

ThermoAnalytics is a leading developer of thermal, fluid flow, and infrared modeling software. Located in Michigan's Upper Peninsula, ThermoAnalytics has been developing the TAITherm thermal simulation software, which models the effects of radiation, conduction, convection, advection, evaporation/condensation, phase change, etc., for over 20 years. They provide software and engineering analysis for complex heat transfer problems. The TAITherm software is used to find solutions for a wide variety of thermal applications, including transient (automotive) brake heating; under-hood, exhaust and underbody heating; HVAC and cabin thermal comfort; battery pack heating for HEVs/EVs; and protecting electronics and other thermally sensitive components. This powerful software offers fast transient thermal analysis and couples to CFD and FEA software, which facilitates an efficient design optimization process. TAITherm finds its greatest use in the automotive, aerospace, heavy vehicle, and railway industries.

# COMSOL Demos

## COMSOL Multiphysics for Thermal and Fluid Analysis
## Tuesday, August 2, 8:00am – 12:00pm, Room 103/104

Instructor: John Dunec, VP of Sales, NW U.S., COMSOL Inc.

John Dunec received his Ph.D. from Stanford in 1983. Prior to joining COMSOL, he had over 20 years of industrial experience: first with IBM, then with an early multiphysics startup, then running a successful product development firm. As a consultant, he was COMSOL's first U.S. customer and is now Vice President of Sales, NW U.S., and Manager of the Palo Alto office. He has been teaching a wide range of COMSOL courses throughout the U.S. since 2003.

COMSOL Multiphysics® is a general-purpose analysis platform, based on advanced numerical methods, for modeling and simulating a wide range of single-physics or coupled-multiphysics phenomena. These include: fluid flow, heat transfer, mass transfer, chemical reactions, structural mechanics, acoustics, electromagnetics, optics, particle tracing and combinations thereof. This workshop will concentrate on COMSOL's thermal and fluid-flow capabilities, sometimes coupled with other physics. Through lecture and a series of worked examples we will explore laminar and turbulent flow, fluid-structure interaction (FSI), thermal radiation, convection and conduction as well as reactive and multiphase flows. Workshop participants will see how easy this software is to learn, get a flavor of its power and adaptability, and explore its wide range of application in the thermal-fluid arena.

## Coupling Between Physics, Between Scale, and Between Solutions With COMSOL Multiphysics
## Thursday, August 4, 3:00pm – 5:00pm, Room 117

Instructor: John Dunec, VP of Sales, NW U.S., COMSOL Inc.

COMSOL Multiphysics® makes it easy to link multiple physics together either as fully coupled (probably nonlinear) problems or to solve one physics based on the results of another. You can also link between dimension (say, simultaneously 2D and 3D) or between solutions. This demo is designed to show a variety of coupling techniques over a wide range of physics. One particular problem we will build and run involves a combination of thermal expansion due to microwave heating with surface currents, involving both structural shells and solids, with forced convective cooling using both convection coefficients and full CFD simulations. It is purposely designed to involve a large number of physics coupled in a variety of different ways. Those new to COMSOL will see how easy it is to set up and solve models in COMSOL, those more experienced will see advanced methods to link between physics and link between solutions. COMSOL Multiphysics® is a general-purpose analysis platform, based on advanced numerical methods, for modeling and simulating a wide range of single-physics or coupled-multiphysics phenomena.

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## Keynote Speaker (Banquet):
## Wednesday, August 3, 7:00pm – 8:00pm, Michael's at Shoreline

## Liquefying Hybrid Rocket Propulsion

Gregory Zilliac, NASA Ames Research Center

Gregory Zilliac earned his M.S. in Aerospace Engineering in 1983 at the Pennsylvania State University. Emphasis of course work was in fluid dynamics. His Master's thesis concerned the development of a high angle-of-attack aerodynamic model that was employed in a six degree-of-freedom analysis of a spinning aircraft.

He earned his Diploma in Aerospace Engineering in 1982 at the von Karman Institute for Fluid Dynamics, Brussels, Belgium. A year-long program that dealt with theoretical and experimental aspects of fluid dynamics. His Diploma project involved the development of a model of turbulent boundary layer separation on an airfoil.

He earned his B.S. in Aerospace Engineering in 1979 at the Parks College of Saint Louis University. From 1982 to present he has worked as a Research Scientist at NASA Ames Research Center where he performed experiments and computations in the field of fluid dynamics, aerodynamics, combustion and instrumentation development. Currently he is the Hybrid Combustion Project lead and also the Fluid Dynamics Group lead. From 2004 to present he is an instructor at Stanford University where he teaches the AA284 Propulsion System Design class.

Over the last decade, a concerted effort has been underway to develop liquefying hybrid rocket propulsion. This technology offers the promise of clean, high performing and relatively safe rocket propulsion at a lower cost than traditional rocket propulsion systems. Like conventional hybrid rockets, a diffusion flame forms in the combustion chamber but in a liquefying hybrid, the diffusion flame is fed by a spray of fuel emanating from a thin liquid melt layer driven by the oxidizer flow adjacent to the fuel surface. The resulting fuel mass flow rate is three to four time greater than the fastest burning conventional hybrid rocket fuel. The high burn rate of the paraffin-based fuels enables the design of high performance rocket motors that are suitable for missions ranging from boosters to in-space motors. This technology, being jointly developed by NASA Ames Research Center, Stanford University and Space Propulsion Group Inc., has matured to the point where flight-weight motors are being fabricated, ground tested and flown. The origin, current status and future of liquefying hybrid rocket propulsion will be discussed.

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## Invited Speakers (lunchtime):
**Monday, August 1, 12:25pm – 1:00pm, Room 171**

### A Mechanically Deployable Entry System Development for Human Mars and Robotic Science Missions

Ethiraj Venkatapathy, NASA Ames Research Center

Ethiraj Venkatapathy earned his Bachelor of Technology in Aeronautical Engineering from Indian Institute of Technology, Madras, India and his Ph.D. in Aerospace Engineering from Iowa State University at Ames, Iowa. He served as the President and Director of Research for ELORET Corp., a small science and technology company in the Silicon Valley and also conducted his own research in hypersonic entry physics supporting NASA between (1985 – 2002). In 2003, he jointed NASA Ames Research Center (ARC) and is currently the Chief Technologist for the Entry Systems and Technology Division at NASA ARC specializing in advanced Entry Systems concepts and thermal protections systems technology development for robotic science and human missions. He is currently leading the technology development efforts, as the project manager for the "Advanced TPS Materials" project for the Game Changing Development Program and as the Principal Technologist for the mechanically deployable semi-rigid ADEPT project. In addition, he is the chief technologist for the Asteroid Threat Assessment Project led by NASA ARC. He also supports the Asteroid Threat Assessment Project as chief technologist in support of NASA's Planetary Defense Program. He is the Co-inventor of the ADEPT, a mechanically deployable entry system concept as well as 3-D Woven TPS (3-D MAT and HEEET) concepts. In 2015, he was recognized by STMD Mission Directorate at NASA with a Leadership Award for his leadership and dedication in providing NASA and the Nation with revolutionary new technologies and capabilities. He is one of the two NASA Ames' Associate Fellows selected in 2015 and Associate Fellow of the AIAA. He was recognized as He received NASA's "Exceptional Technology Achievement Medal" in 2012 and NASA's Outstanding Leadership Medal twice (in 2007 and in 2010).

**Tuesday, August. 2, 12:25pm – 1:00pm, Room 171**

### A Pathway to Innovation

Dan Rasky, NASA Ames Research Center

Dr. Rasky is an internationally recognized expert on advanced entry systems and thermal protection materials. He has developed his expertise working five years for the U.S. Air Force and more than 20 years for NASA. In the 1990's, he and his research colleagues at NASA Ames Research Center, invented a heat-shield material called Phenolic Impregnated Carbon Ablator (PICA) that has subsequently been used on several NASA, as well as private industry, spacecraft. For this achievement, Rasky received the NASA Inventor of the Year Award for 2007 – the first ever for NASA Ames.

In 2009, Rasky completed a one-year Interagency Personnel Assignment (IPA) with the Space Grant Education and Enterprise Institute, Inc., San Diego, Calif., where he served as a senior research Fellow supporting a number of emerging space companies and other organizations. One of these companies was Space Exploration Technologies Corp., Hawthorne, Calif., also known as SpaceX. Rasky spent considerable time at SpaceX providing expert consultation about the design and development of the heat-shield for their Dragon spacecraft. As a result, SpaceX chose PICA as the heat shield material for the spacecraft. On December 8, 2010, the Falcon-9 rocket carried the Dragon capsule with its SpaceX fabricated PICA-X heat shield into space. It survived the launch and re-entry into Earth's atmosphere; consequently, the mission was considered an enormous success.

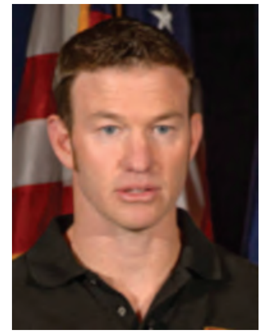
In addition to the SpaceX Dragon capsule, Rasky has made significant contributions to flight hardware used on eight NASA missions, including the NASA Stardust comet sample return mission. The Stardust return capsule used a PICA heat-shield that enabled the mission, and was the fastest entry ever by a man-made object at Earth. It is now on display as part of the "Milestones of Flight" exhibit at the Smithsonian Institution in Washington D.C. PICA also is being used for the primary heatshield for the upcoming Mars Science Laboratory (MSL) lander mission.

Today, Rasky is the director and co-founder of the Space Portal at the NASA Research Park, Moffett Field, Calif. The Space Portal has a mission to "be a friendly front door for emerging and non-traditional space companies." Through their initiatives and collaborations the Space Portal has had a significant role in the establishment of several notable and successful NASA programs, including the Commercial Orbital Transportation Systems (COTS) program, the Innovative Lunar Demonstration Data (ILDD) program, and the Commercial Reusable Suborbital Research (CRuSR) program.

Rasky also is the recipient of the Senior Professional Meritorious Presidential Rank Award, the NASA Exceptional Achievement Award, the NASA Exceptional Service Medal, 12 NASA Group Awards, and eight Space Act Awards. He has six patents, 64 publications, and is an associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and a senior member of the American Society of Mechanical Engineers (ASME).

**Wednesday, August 3, 12:25pm – 1:00pm, Room 171**

## Orion Exploration Flight Test One (EFT-1) Spacecraft Recovery and Thermal Protection System (TPS) Assessment



Jeremy Vander Kam, NASA Ames Research Center

Jeremy Vander Kam is the Deputy System Manger for the Orion Thermal Protection System (TPS). Jeremy's been working on Orion since its inception in 2006 overseeing the arc jet test program at NASA Ames, coordinating flight readiness assessments, and defining spacecraft recovery requirements supporting TPS and Aeroscience flight test objectives. Jeremy joined NASA in 2000 after receiving a B.S. and M.S. in aeronautical engineering from UC Davis.

**Thursday August 4, 12:25pm – 1:00pm, Room 171**

## Hydrocode Modeling of Asteroid Entry, Airburst, and Impacts for Hazard Assessment

Darrel Robertson, NASA Ames Research Center

Darrel Robertson is an aerospace engineer in the Engineering Risk Assessment group at NASA Ames Research Center. As part of NASA's Asteroid Threat Assessment Project he has modeled the break-up and airburst of small asteroids such as the Chelyabinsk event and larger impacts into water for tsunami prediction. He earned his B.S. in Physics with Space Science from Leicester University in the UK, and his M.S. and Ph.D. in Aeronautics and Astronautics from the Massachusetts Institute of Technology.

**Conference Planning Committee:**

Conference Chair: Shishir Pandya

Abstract Review and Paper sessions: Monica Guzik
Session Chairs: Ryan D. Edewards, Joshua Fody, Eric Lira, A. J. Mastropietro,
Timothy, K. Risch, William Q. Walker, Ruwan Somawardhana

Venue: Claudia Rico-Tapia

Vendor Participation: Callie McKelvey

Short Courses: Chun Tang

Web Curator: Monica Guzik

Lunch and Welcome Reception: Claudia Rico-Tapia

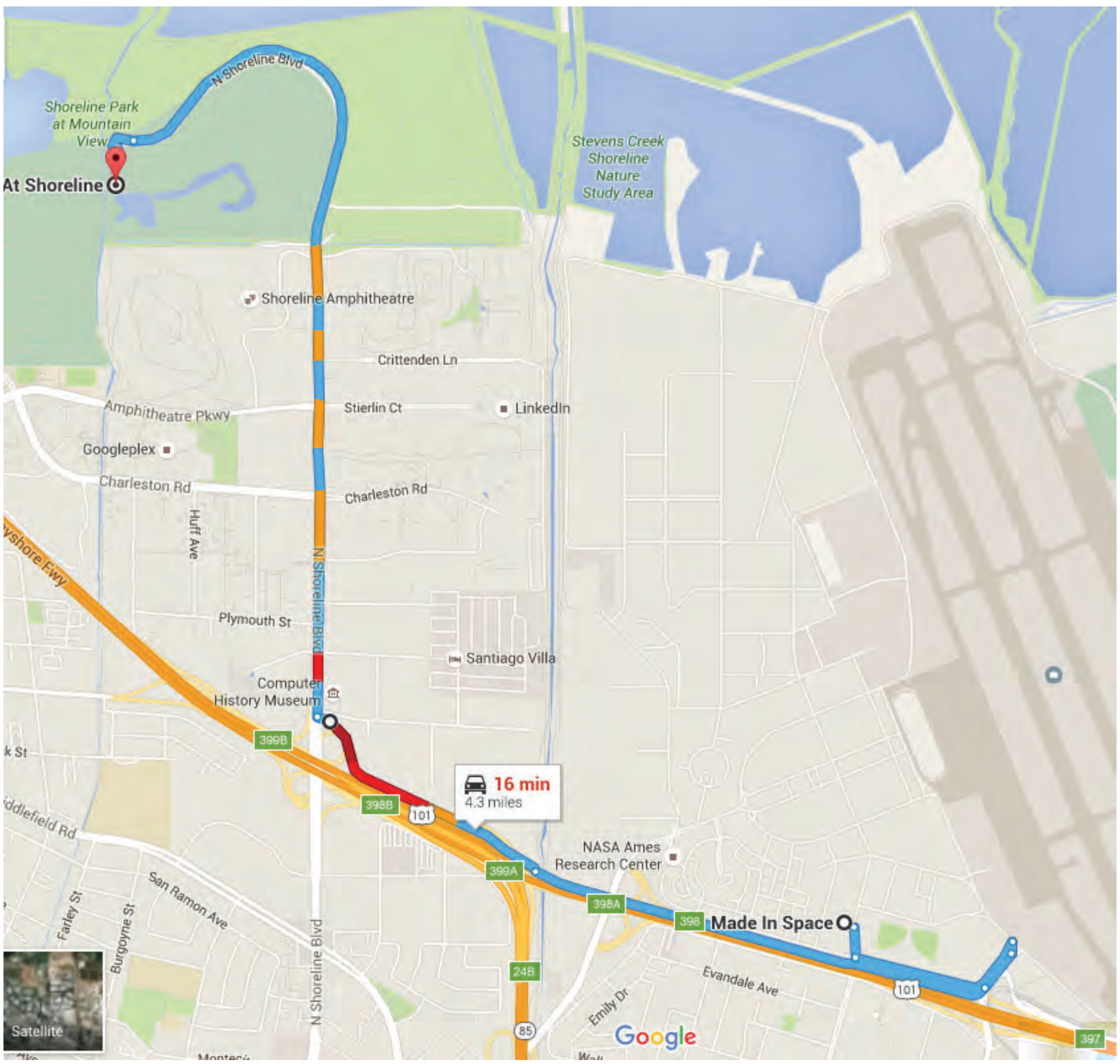
Tour Planning: Gina Morello, Carolina Rudisel

Activities Planning: Robin Beck

On-site setup, registration: Gina Morello, Claudia Rico-Tapia

Program/agenda graphics: Marco Librero

Directions to Michael's At Shoreline
Leave base through either the Ellis or Main gate
Then take 101N
Take the Shoreline ave. exit
Make a RIGHT onto Shoreline
Go straight until you arrive at Michael's (you will need to go through an unattended gate)



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