National Aeronautics and
Space Administration

25th ANNUAL

THERMAL AND FLUIDS ANALYSIS WORKSHOP (TFAWS) 2014

25 YEARS OF INNOVATION AND COLLABORATION

AUGUST 4 to 8, 2014

CLEVELAND, OH

The Thermal Analysis Workshop (TAWS) was first held in 1989 at Glenn Research Center (GRC), then Lewis Research Center (LeRC) thanks to the efforts of LeRC's Thermal and Fluids Analysis branch. Prompted by the Space Station Freedom thermal analysis software requirements, the workshop was intended to be a forum at which analysts from all NASA centers could get together and discuss the latest thermal analytical practices, strategies, and tools. The event was hosted at LeRC's main auditorium, where 8 papers were presented to an audience of over 100 NASA thermal engineers. The following year, both hands-on software training and a debut software presentation for a new thermal tool were added to the agenda. Then, in 1991, TAWS became TFAWS, the Thermal and Fluids Analysis Workshop, to include a second and highly intertwined discipline—fluids analysis. After several years in which TFAWS was hosted exclusively by GRC, a TFAWS Delegates Committee was formed with representatives from each center and it was decided that the hosting role would begin to alternate between NASA centers in an effort to both alleviate the planning efforts on the GRC team as well as promote greater involvement across the Agency. In 2010, the NASA Engineering and Safety Committee (NESC) began sponsoring the workshop through three of its technical discipline teams: Passive Thermal, Life Sciences/Active Thermal, and Aerosciences.

TFAWS continues to grow in attendance and content each year. Attendees include engineers and scientists from every NASA center as well as other Government agencies, industry partners, academia, and international entities. At present, the conference agenda boasts paper sessions, hands-on software training, hardware and software demonstrations, technical short courses, guest speakers, and tours of various facilities at the hosting NASA center. In addition, evening networking events help promote synergy and communication among attendees and their respective organizations.

Glenn Research Center is honored to be hosting TFAWS this year for its 25th "Silver" Anniversary, bringing the event back to its roots. We are so happy to have you join us to celebrate 25 Years of Innovation and Collaboration this August 4 to 8, 2014.

Here's to years past and many years to come.

Table of Contents

Overview of TFAWS 2014 1
Agenda Summary: Monday, August 4 2
Agenda Summary: Tuesday, August 5 3
Agenda Summary: Wednesday, August 6 4
Agenda Summary: Thursday, August 7 5
Agenda Summary: Friday, August 8 6
Map of Meeting Space at The Cleveland Convention Center 7
Session Descriptions: Monday, August 4 8
Session Descriptions: Tuesday, August 5 12
Session Descriptions: Wednesday, August 6 16
Session Descriptions: Thursday, August 7 21
Lunchtime Speakers 26
Keynote Speaker 28
NASA Glenn Research Center Site Tours at Lewis Field 29
NASA Glenn Research Center Site Tours at Plum Brook Station 30
Paper Abstracts: Active Thermal 31
  Active Thermal Paper Session I 31
    CFD Analysis of Thermal Control System Using NX Thermal & Flow 31
    Thermal Analysis of Cryogenic Hydrogen Liquid Separator 31
    Application of CFD to Simulate Water Droplet Impingements for Aircraft Icing Analysis 32
    One Dimensional Analysis Model of a Condensing Spray Chamber Including Rocket Exhaust Using SINDA/FLUINT and CEA 33
    Different Kinds of Heat Pipes 34
  Active Thermal Paper Session II 35
    Water Based Phase Change Material Heat Exchanger Development 35
    Launch Vehicle Avionics Passive Thermal Management 36
    Spacesuit Water Membrane Evaporator, An Enhanced Evaporative Cooling System for the Advanced Extravehicular Mobility Unit Portable Life Support System 36
    Mini-Membrane Evaporator for Contingency Spacesuit Cooling 37
    Low Cost Radiator for Fission Power Thermal Control 38
    SINDA/FLUINT Stratified Tank Modeling for Cryogenic Propellant Tanks 38
Paper Abstracts: Passive Thermal 39

Passive Thermal Paper Session I 39
Adaptation of 25-Node Human Thermal Model for Use in Sierra Nevada Corporation's Dream Chaser® System-Level Thermal Desktop Model 39
Precision Tracking Space System (PTSS) Infrared Sensor Thermal Testing and Model Correlation 40
Preliminary Development of a TSS and SINDA/FLUINT to ESARAD/ESATAN Thermal Model Converter 40
Thermal Control Design for the Subarcsecond Telescope and Balloon Experiment (STABLE) 41
LUROVA – From Render Engine to Thermal Model 42
Thermal Modeling and Test Correlation for the High Fidelity Data Acquisition System 42
Passive Thermal Paper Session II 43
Thermal Interface Materials and Challenges Faced by Thermal Interface Material Suppliers Jason Strader, Laird 43
LTCS (Laser Thermal Control System) Test Supporting the Improvement of DeCoM (Deepak Condenser Model) 43
Using SpaceClaim/TD Direct for Modeling Components With Complex Geometries for the Thermal Desktop-based Advanced Stirling Radioisotope Generator Model 44
Cube Flux Method to Generate Spacecraft Thermal Environments 44
Passive Thermal Design approach for the Space Communications and Navigation (SCaN) experiment on the International Space Station (ISS) 45
Paper Abstracts: Aerothermal 46
A New High Temperature Thermopile Heat Flux Sensor at AEDC (ITAR) 46
Space Shuttle Boundary Layer Transition Flight Experiment Ground Testing Overview 46
Langley Aerothermodynamic Labs: Testing Capabilities 47
Paper Abstracts: Interdisciplinary 48
SRTMV-N2 Plume Impingement Test Panel Thermal Analysis 48
Flow Characteristics of a Strut Injector for Scramjets: Numerical and Experimental Results 49
Thermal Acoustic Oscillation: Causes, Detection, Analysis and Prevention 49
Acknowledgments 50

Overview of TFAWS 2014

On behalf of the NASA Glenn Research Center, welcome to Cleveland, Ohio! The 25th Annual Thermal and Fluids Analysis Workshop (TFAWS), sponsored by the NASA Engineering and Safety Center (NESC) and hosted by the Glenn Research Center (GRC), is being held at the Cleveland Convention Center from August 4 to 8, 2014.

TFAWS was designed to encourage knowledge sharing, professional development, and networking throughout the thermal and fluids engineering disciplines within NASA and beyond. The vision of TFAWS is to maintain continuity over time and between disciplines throughout the thermal and fluids engineering community. This year's conference theme is ***25 Years of Thermal and Fluids Innovation and Collaboration***. The three technical areas of focus are Passive Thermal Control, Life Support/Active Thermal, and Aerothermal.

The notable benefits of attending TFAWS include the following:

- Participants have the opportunity to share their work on the latest application of new and established methods to aerospace missions, impart engineering lessons learned, and compare/contrast engineering practices.
- Annual sharing of knowledge, hands-on instruction in relevant state-of-the-art engineering analysis tools, and seminars/short courses taught by experts and veterans in the thermal and fluids engineering disciplines, helps to ensure that expertise of the community is maintained.
- Networking at TFAWS gives each attendee an extensive network of contacts, serving as an excellent source for advice and technical knowledge.
- TFAWS provides tremendous opportunities for enhancing collaboration between NASA centers, other government agencies, industry, academia, and the international thermal and fluids engineering community.

Bringing together such a large sampling of the thermal and fluids community helps to ensure that perspectives are broadened and working relationships are maintained and expanded. This sharing of expertise between NASA centers and those in other government agencies, industry, academia, and international partners helps fuel the qualities of communication, teamwork, and technical excellence that are integral to NASA's core values. The conference's emphasis on teamwork with fellow professionals is a strategic component of an environment promoting the importance of safety, quality of work, and mission success.

You can visit TFAWS on our website for more information: https://tfaws.nasa.gov/tfaws14

Like/Follow @TFAWS on Social Media with **#TFAWS2014:** https://www.facebook.com/TFAWS
https://twitter.com/TFAWS

Agenda Summary: Monday, August 4

<table>
<tr><th>Time</th><th>Room 1</th><th>Room 3</th><th>Room 4</th><th>Room 5</th><th>Room 6</th><th>Other</th></tr>
<tr><td>7:30 AM</td><td colspan="6">Registration Open, Breakfast Items Available for Purchase</td></tr>
<tr><td>8:00 AM</td><td rowspan="4">Active Thermal Paper Session I (part 1/2)</td><td rowspan="4">FEAR Software Training</td><td rowspan="4">TARP Software Training (part 1/2)</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>8:30 AM</td></tr>
<tr><td>9:00 AM</td></tr>
<tr><td>9:30 AM</td></tr>
<tr><td>9:45 AM</td><td colspan="6">Morning Break – Vendor Tables Open and Refreshments Available for Purchase</td></tr>
<tr><td>10:00 AM</td><td rowspan="4">Active Thermal Paper Session I (part 2/2)</td><td rowspan="4">Thermal Desktop Software Training</td><td rowspan="4">TARP Software Training (part 2/2)</td><td rowspan="4">ANSA & μETA for CFD Demo</td><td rowspan="4">Fundamentals of Cryogenics and Cryogenic Analysis (part 1/2)</td><td rowspan="4"></td></tr>
<tr><td>10:30 AM</td></tr>
<tr><td>11:00 AM</td></tr>
<tr><td>11:30 AM</td></tr>
<tr><td>11:45 AM</td><td colspan="6" rowspan="2">Lunch Speaker Session:
Steven L. Rickman – A History of Spacecraft Analysis, Then and Now</td></tr>
<tr><td>12:30 PM</td></tr>
<tr><td>1:15 PM</td><td rowspan="4"></td><td rowspan="4">Thermal Desktop/ RadCAD Software Training</td><td rowspan="4">ANSA & μETA for CFD Software Training (part 1/2)</td><td rowspan="4"></td><td rowspan="4">Fundamentals of Cryogenics and Cryogenic Analysis (part 2/2)</td><td rowspan="4"></td></tr>
<tr><td>1:30 PM</td></tr>
<tr><td>2:00 PM</td></tr>
<tr><td>2:30 PM</td></tr>
<tr><td>3:00 PM</td><td colspan="6">Afternoon Break – Vendor Tables Open and Refreshments Available for Purchase</td></tr>
<tr><td>3:15 PM</td><td rowspan="4"></td><td rowspan="4">FloCAD Software Training</td><td rowspan="4">ANSA & μETA for CFD Software Training (part 2/2)</td><td rowspan="2">TSS Capabilities</td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>3:30 PM</td></tr>
<tr><td>4:00 PM</td><td rowspan="2"></td></tr>
<tr><td>4:30 PM</td></tr>
<tr><td>5:00 PM</td><td colspan="6">Adjourn</td></tr>
<tr><td>Evening</td><td colspan="6">TFAWS 2014 Welcome Reception</td></tr>
</table>

Agenda Summary: Tuesday, August 5

Time	Room 1	Room 3	Room 4	Room 5	Room 6	Other
7:30 AM	Registration Open, Breakfast Items Available for Purchase					
8:00 AM 8:30 AM 9:00 AM 9:30 AM		TD Direct Software Training ***(part 1/2)***	Intro to TSS Software Training ***(part 1/4)***	Passive Thermal TDT Meeting (invite only) ***(part 1/2)***	Mission Success First: Lessons Learned ***(part 1/2)***	
9:45 AM	Morning Break – Vendor Tables Open and Refreshments Available for Purchase					
10:00 AM 10:30 AM 11:00 AM 11:30 AM		TD Direct Software Training ***(part 2/2)***	Intro to TSS Software Training ***(part 2/4)***	Passive Thermal TDT Meeting (invite only) ***(part 2/2)***	Mission Success First: Lessons Learned ***(part 2/2)***	
11:45 AM 12:30 PM	**Lunch Speaker Session:** Mary F. Wadel - We Freeze to Please – Aircraft Icing					
1:15 PM 1:30 PM 2:00 PM 2:30 PM	Passive Thermal Paper Session I ***(part 1/2)***	Excel Visual Basic for Applications for Engineers	Intro to TSS Software Training ***(part 3/4)***	ANSYS/FLUENT Demo	TESC Meeting (invite only) ***(part 1/2)***	Site Tour of NASA Glenn Research Center at Lewis Field, **Group A**
3:00 PM	Afternoon Break – Vendor Tables Open and Refreshments Available for Purchase					
3:15 PM 3:30 PM 4:00 PM 4:30 PM	Passive Thermal Paper Session I ***(part 2/2)***	COVeR Software Training	Intro to TSS Software Training ***(part 4/4)***	New/Advanced Features of Thermal Desktop	TESC Meeting (invite only) ***(part 2/2)***	
5:00 PM	Adjourn					
Evening	Cleveland Indians Networking Event					

Agenda Summary: Wednesday, August 6

<table>
<tr><th>Time</th><th>Room 1</th><th>Room 3</th><th>Room 4</th><th>Room 5</th><th>Room 6</th><th>Other</th></tr>
<tr><td>7:30 AM</td><td colspan="6">Registration Open, Breakfast Items Available for Purchase</td></tr>
<tr><td>8:00 AM</td><td rowspan="4">Aerothermal Paper Session (ITAR Session*) (part 1/2)</td><td rowspan="4">NX Thermal/Flow (MAYA) Software Training</td><td rowspan="4">ANSYS/FLUENT Software Training (part 1/2)</td><td rowspan="4">TARP and COVeR Capabilities Demo</td><td rowspan="4">On-Orbit Thermal Environments Course (part 1/2)</td><td rowspan="4"></td></tr>
<tr><td>8:30 AM</td></tr>
<tr><td>9:00 AM</td></tr>
<tr><td>9:30 AM</td></tr>
<tr><td>9:45 AM</td><td colspan="6">Morning Break – Vendor Tables Open and Refreshments Available for Purchase</td></tr>
<tr><td>10:00 AM</td><td rowspan="4">Aerothermal Paper Session (part 2/2)</td><td rowspan="4">Femap Thermal/Flow (MAYA) Software Training</td><td rowspan="4">ANSYS/FLUENT Software Training (part 2/2)</td><td rowspan="4">ANSA for Morphing & Optimization Demo</td><td rowspan="4">On-Orbit Thermal Environments Course (part 2/2)</td><td rowspan="4"></td></tr>
<tr><td>10:30 AM</td></tr>
<tr><td>11:00 AM</td></tr>
<tr><td>11:30 AM</td></tr>
<tr><td>11:45 AM</td><td colspan="6" rowspan="2">Lunch Speaker Session:
Dr. Geoffrey A. Landis – Ten Years of Mars</td></tr>
<tr><td>12:30 PM</td></tr>
<tr><td>1:15 PM</td><td rowspan="4">Active Thermal Paper Session II (part 1/2)</td><td rowspan="4">GFSSP Software Training (part 1/2)</td><td rowspan="4">ANSA for Morphing & Optimization Software Training (part 1/2)</td><td rowspan="4">FIAT Training Course (part 1/2)</td><td rowspan="4">Thermal Testing Course (part 1/2)</td><td rowspan="9"></td></tr>
<tr><td>1:30 PM</td></tr>
<tr><td>2:00 PM</td></tr>
<tr><td>2:30 PM</td></tr>
<tr><td>3:00 PM</td><td colspan="5">Afternoon Break – Vendor Tables Open and Refreshments Available for Purchase</td></tr>
<tr><td>3:15 PM</td><td rowspan="4">Active Thermal Paper Session II (part 2/2)</td><td rowspan="4">GFSSP Software Training (part 2/2)</td><td rowspan="4">ANSA for Morphing & Optimization Software Training (part 2/2)</td><td rowspan="4">FIAT Training Course (part 2/2)</td><td rowspan="4">Thermal Testing Course (part 2/2)</td></tr>
<tr><td>3:30 PM</td></tr>
<tr><td>4:00 PM</td></tr>
<tr><td>4:30 PM</td></tr>
<tr><td>5:00 PM</td><td colspan="6">Adjourn</td></tr>
<tr><td>Evening</td><td colspan="6">TFAWS 2014 Keynote Dinner</td></tr>
</table>

*Only U.S. citizens and U.S. Permanent Residents are permitted to attend ITAR sessions.

Agenda Summary: Thursday, August 7

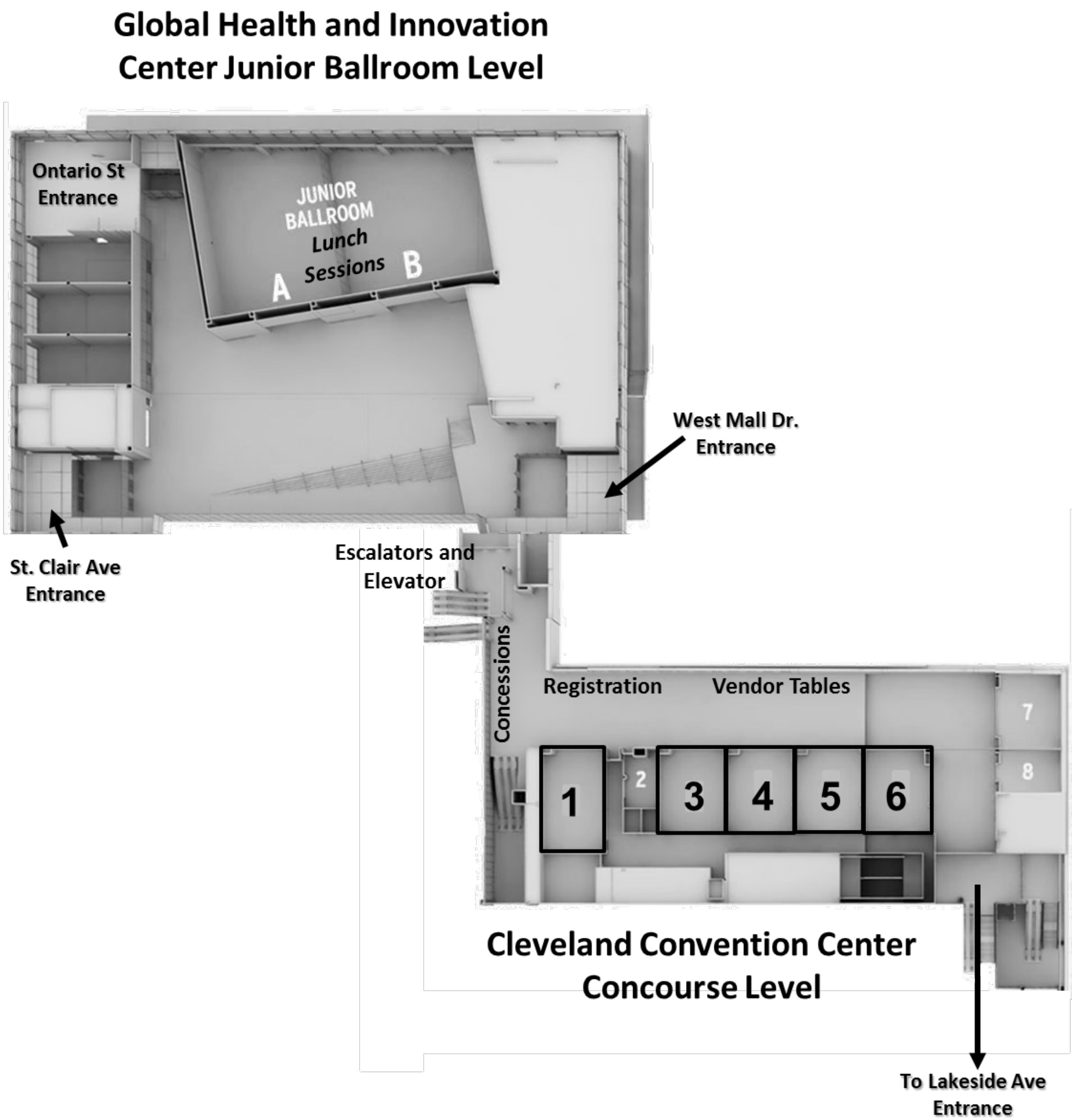
Time	Room 1	Room 3	Room 4	Room 5	Room 6	Other
7:30 AM	Registration Open, Breakfast Items Available for Purchase					
8:00 AM	Passive Thermal Paper Session II ***(part 1/2)***	Non-Grey Body Heat Transfer Course ***(part 1/2)***	TSS Advanced Software Training ***(part 1/4)***	MSC Apex Demo	MMOD Protection and Degradation Effects ***(part 1/2)***	
8:30 AM						
9:00 AM						
9:30 AM						
9:45 AM	Morning Break – Vendor Tables Open and Refreshments Available for Purchase					
10:00 AM	Passive Thermal Paper Session II ***(part 2/2)***	Non-Grey Body Heat Transfer Course ***(part 2/2)***	TSS Advanced Software Training ***(part 2/4)***	NX Thermal/Flow Demo	MMOD Protection and Degradation Effects ***(part 2/2)***	
10:30 AM						
11:00 AM				GFSSP Demo		
11:30 AM						
11:45 AM	**Lunch Speaker Session:** Steven M. Iden - Optimized Integrated Multidisciplinary Systems (OPTIMUS)					
12:30 PM						
1:15 PM	Interdisciplinary Paper Session	COMSOL Multiphysics Software Training ***(part 1/2)***	TSS Advanced Software Training ***(part 3/4)***	SpaceClaim Engineer 2012+	Two-Phase Flow and Heat Transfer ***(part 1/2)***	Site Tour of NASA Glenn Research Center at Lewis Field, **Group B**
1:30 PM						
2:00 PM						
2:30 PM						
3:00 PM	Afternoon Break – Vendor Tables Open and Refreshments Available for Purchase					
3:15 PM		COMSOL Multiphysics Software Training ***(part 2/2)***	TSS Advanced Software Training ***(part 4/4)***		Two-Phase Flow and Heat Transfer ***(part 2/2)***	
3:30 PM						
4:00 PM				Delegate's Meeting (invite only) 4-6 pm		
4:30 PM						
5:00 PM	Adjourn					
Evening	Nautica Queen Dining and Sightseeing Sunset Cruise					

Agenda Summary: Friday, August 8

Time	Other
7:30 AM	Assemble At Lakeside Ave Entrance of Convention Center ***[Buses Depart at 8 am]***
8:00 AM	Site Tour of NASA Glenn Research Center at Plum Brook Station
9:00 AM	
10:00 AM	
11:00 AM	
12:00 PM	
1:00 PM	Return to Convention Center; TFAWS 2014 is Adjourned

Please meet in front of the Lakeview Ave. entrance of the Cleveland Convention Center by 7:45 am to ensure that you do not miss the bus departure time. See pages 29 and 30 for more information.

Map of Meeting Space at The Cleveland Convention Center



Session Descriptions: Monday, August 4

Active Thermal Paper Session I
8:00 am – 11:00 am
Room 1
Session Chairs: Steve Barsi (NASA-GRC) & Craig Dinsmore (NASA JSC)

8:00 AM	TFAWS2014-AT-01	"CFD Analysis of Thermal Control System Using NX Thermal & Flow" *Presenter: Craig Fortier (NASA KSC*)
8:30 AM	TFAWS2014-AT-02	"Thermal Analysis of Cryogenic Hydrogen Liquid Separator" *Presenter: Craig Fortier (NASA KSC)*
9:00 AM	TFAWS2014-AT-03	"Application of CFD to Simulate Water Droplet Impingements for Aircraft Icing Analysis" *Presenter: Nili Bachchan (Metacomp Technologies)*
9:30 AM	TFAWS2014-AT-04	"One Dimensional Analysis Model of a Condensing Spray Chamber Including Rocket Exhaust Using SINDA/FLUINT and CEA" *Presenter: Barbara Sakowski (NASA GRC)*
10:30 AM	TFAWS2014-AT-05	"Different Kinds of Heat Pipes" *Presenter: Bill Anderson (ACT, Inc.)*

FEAR Software Training
8:00 am – 9:45 am
Room 3
Instructor: Dr. John Dec (NASA LaRC)

The Finite Element Ablation and Thermal Response Design and Analysis Program (FEAR) is a multidimensional, multiphysics analysis tool capable of simulating the transient thermostructural response of thermal protection systems. FEAR has the ability to analyze any geometry consisting of thermal protection, bonding, and structural materials subject to aerothermal heating on any boundary. Radiative heating and cooling, pyrolysis gas velocity, pressure, and structural displacement can be specified on any point, curve, surface, or solid. In addition, other boundary conditions such as specified temperature, specified heat flux, or temperature based convective heating or cooling may be applied to any point, curve, surface, or solid. FEAR makes use of the MSC Patran® preprocessor to process and mesh the geometry, as well as applying boundary conditions. FEAR is more than just an analysis tool; it was designed to be the backbone of a probabilistic thermal protection system design framework. In this short course, an overview of FEAR and the probabilistic design process will be presented. A detailed description of the governing differential equations solved by FEAR, numerical procedures used, and the input/output will be discussed. Depending on time, an end to end example will be presented.

TARP Software Training
8:00 am – 11:45 am
Room 4
Instructor: Hume Peabody (Thermal Modeling Solutions, LLC)

TARP is a Windows based post-processing program that creates an interface between the ASCII output from numerous thermal analysis solvers and Microsoft Excel. Users define the post processing objects within the TARP environment to create in the output Excel workbook, including: DataSets, Plots, Tables, etc. A user also has the ability to define further data points, such as group averages, maximums, and minimums. Lastly, a feature exists for the creation of a specialized workbook for the evaluation of nodal heatflows, which can be further extended to heatflows between the defined groups.

Introduction to C&R Thermal Desktop®, RadCAD®, and FloCAD® Software Training
10:00 am – 5:00 pm
Room 3
Instructor: Douglas Bell (CR Tech)

This session will provide an introduction to the capabilities of Thermal Desktop, RadCAD, 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.

ANSA & μETA for CFD Demonstration
10:00 am – 11:45 am
Room 5
Instructors: Pravin Peddiraju & Jonathan Krueger (BETA CAE Systems)

This demonstration aims to provide the audience with a brief overview of the capabilities that are present in ANSA & μETA for CFD. A sample test case will be used to show features such as:

- geometry healing and manipulation,
- surface meshing,
- layers generation and volume meshing,
- morphing and optimization
- visualization and reporting

Fundamentals of Cryogenics and Cryogenic Analysis
10:00 am – 3:00 pm
Room 6
Instructors: Wesley Johnson, Thomas Tomsik, & Jeffrey Moder (NASA GRC)

Analysis of the extreme conditions that are encountered in cryogenic systems requires the most effort out of analysts and engineers. Due to the costs and complexity associated with the extremely cold temperatures involved, testing is sometimes minimized and extra analysis is often relied upon. This short course is designed as an introduction to cryogenic engineering and analysis, and it is intended to introduce the basic concepts related to cryogenic analysis and testing as well as help the analyst understand the impacts of various requests on a test facility. Discussion will revolve around operational functions often found in cryogenic systems, hardware for both tests and facilities, and what design or modelling tools are available for performing the analysis. Emphasis will be placed on what scenarios to use what hardware or the analysis tools to get the desired results. The class will provide a review of first principles, engineering practices, and those relations directly applicable to this subject including such topics as cryogenic fluids, thermodynamics and heat transfer, material properties at low temperature, insulation, cryogenic equipment, instrumentation, refrigeration, testing of cryogenic systems, cryogenics safety and typical thermal and fluid analysis used by the engineer. The class will provide references for further learning on various topics in cryogenics for those who want to dive deeper into the subject or have encountered specific problems.

Lunch: History of Spacecraft Thermal Analysis, Then and Now
12:00 pm – 1:00 pm
Junior Ballroom
Speaker: Steven L. Rickman (NESC)

ANSA & μETA for CFD Software Training
1:15 pm – 5:00 pm
Room 4
Instructors: Pravin Peddiraju & Jonathan Krueger (BETA CAE Systems)

The purpose of this short course is to provide attendees with hands on exposure to the geometry manipulation and meshing tools available inside ANSA. A step by step tutorial will guide attendees through the complete process of preparing a model for CFD analysis. This will be followed by a short overview of processing the results and preparing a report.

TSS Capabilities Demonstration
3:15 pm – 4:00 pm
Room 5
Instructors: Joe Lepore & Joe Clay (Spacedesign Corp.)

Interoperability of thermal analysis, structural analysis and rapid prototyping with a single Geometry will be discussed. Advances in TSS v14, such as, composite closed loop verification of radiation model boundaries, Executive application, STEP Transfer, direct radiation analysis of CAD models, graphics enhancements, B-spline CAD objects, B-spline construction Surfaces, SindaWin GUI support for Sinda/Fluint, Section 508 Compliance, distributed processing on Linux, LIST speed improvements for reflected and received heating rates, conduction enhancements, OBJ file Transfer with texture maps, construction surface coloring, automated multi-picking for Booleans and base surfaces and many more, will be demonstrated.

Welcome Reception
5:30 pm – 7:00 pm

House of Blues Cleveland
308 Euclid Ave
Cleveland, OH 44144

All attendees and guests are welcome to attend the TFAWS Welcome Cocktail Reception on Monday evening from 5:30 pm to 7:00 pm at the Cambridge Room of the House of Blues Cleveland for a chance to network with thermal and fluids analysis peers as well as NASA Glenn Research Center Management. TFAWS historical slideshows will provide some nostalgia and humor to get the conversation flowing, and a cash bar will be available with beverages for purchase. Please note that you must be at least 21 years of age to consume alcoholic beverages. There is no cost to attend this event.

The House of Blues Cleveland is located in the historic Woolworth building in the East Fourth Street District, just steps away from the Hyatt Regency hotel as well as a myriad of dining and entertainment venues. The Cambridge Room provides a unique and intimate setting for networking as the perfect way to welcome our guests to this very special 25th Thermal and Fluids Analysis Workshop. Please join us in celebrating!

Session Descriptions: Tuesday, August 5

Introduction to CRTech TD Direct® Software Training
8:00 am – 11:45 am
Room 3
Instructor: Douglas Bell (CR Tech)

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 SpaceClaim Corporation's SpaceClaim Engineer, 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.

Introduction to TSS Software Training
8:00 am – 5:00 pm
Room 4
Instructors: Joe Lepore & Joe Clay (Spacedesign Corp.)

This hands-on class will progress through a thermal analysis of a spacecraft. 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.

Passive Thermal Technical Discipline Team Meeting – Invite Only
8:00 am – 11:45 am
Room 5

Mission Success First: Lessons Learned
8:00 am – 11:45 am
Room 6
Instructors: Joe Nieberding & Larry Ross (Aerospace Engineering Associates, Inc.)

What went wrong? How did it happen? Could it happen again? How can we avoid repeating the mistakes of the past? No one knows like the people who were there, and have the scars to prove it from personal involvement in space mission failures. The majority of aerospace mishaps can be traced to easily recognized, preventable root causes resulting from a lack of quality somewhere in the system. Most missions are lost to human error, not rocket science.

Examining and understanding these causes for more than forty actual aerospace mission failures is critical to helping today's designers of any highly complex systems, aerospace or otherwise, identify system specific lessons that must be learned. These lessons are not unique to programs or time. They apply across multiple aerospace and non-aerospace endeavors. The same mistakes are being made today that were made fifty years ago. Implementing specific strategies and project "Rules of Practice" early in a program is the best means of prevention. Recognizing why the lessons of the past were not learned is also a critically important step in solving the problem. The "Mission Success First: Lessons Learned" class is "words from the wise" aimed at further strengthening system quality standards by understanding why they broke down in the past, and what to do about it. This class is among NASA's most highly acclaimed classes. The importance of the topic has been recognized by NASA and the United States Aerospace community through invitations to present this class more than seventy times in the United States, Europe, and Asia over the past seven years.

Lunch: We Freeze To Please – Aircraft Icing
12:00 pm – 1:00 pm
Junior Ballroom
Speaker: Mary F. Wadel (NASA GRC)

Site Tour of NASA Glenn Research Center at Lewis Field (Group A)
1:15 pm – 5:00 pm

Please meet in front of the Lakeview Ave. entrance of the Cleveland Convention Center by 1:00 pm to ensure that you do not miss the bus departure time. See pages 29 and 30 for more information.

Passive Thermal Paper Session I
1:15 pm – 5:00 pm
Room 1
Session Chairs: Laurie Carrillo (NASA JSC) & A.J. Mastropietro (NASA JPL)

1:15 PM	TFAWS2014-PT-01	"Adaptation of 25-Node Human Thermal Model for use in Sierra Nevada's Dream Chaser® System-Level Thermal Desktop Model" *Presenter: James Byerly (Sierra Nevada Corp)*
1:45 PM	TFAWS2014-PT-02	"Precision Tracking Space System (PTSS) Infrared Sensor Thermal Testing and Model Correlation" *Presenter: Carl Ercol (JHUAPL)*
2:15 PM	TFAWS2014-PT-03	"Preliminary Development of a TSS and SINDA/FLUINT to ESARAD/ESATAN Thermal Model Converter" *Presenter: Kan Yang (NASA GSFC)*
3:15 PM	TFAWS2014-PT-04	"Thermal Control Design for the Subarcsecond Telescope and BaLloon Experiment (STABLE)" *Presenter: Hared Ochoa (NASA JPL)*

3:45 PM	TFAWS2014-PT-05	"LUROVA – From Render Engine to Thermal Model" *Presenter: Ron Creel (DoD)*
4:15 PM	TFAWS2014-PT-10	"Thermal Modeling and Test Correlation for the High Fidelity Data Acquisition System" *Presenter: Christopher Evans (NASA MSFC)*

Excel Visual Basic for Applications for Engineers
1:15 pm – 3:00 pm
Room 3
Instructor: Matt Moran (NASA GRC)

This course will present a brief overview of how to create engineering models using Excel and its built-in programming environment, Visual Basic for Applications (VBA). Students will be able to follow along with the instructor to perform example problems on the classroom-supplied computers.

ANSYS/FLUENT Demonstration
1:15 pm – 3:00 pm
Room 5
Instructors: Parsa Zamankhan & Valerio Viti (ANSYS, Inc.)

In this session we, through a short presentation, will introduce ANSYS CFD products with an emphasis on A&D applications. Next we will present two demos from our advanced technologies, Adjoint solver and One-way thermal FSI, with applications in space industries.

TESC Meeting – Invite Only
1:15 pm – 5:00 pm
Room 6

COVeR Software Training
3:15 pm – 5:00 pm
Room 3
Instructor: Hume Peabody (Thermal Modeling Solutions, LLC)

COVeR is a new post processing environment nearing completion to allow a user to quickly find and display nodes or groups of interest, leveraging the data structures used in TARP. It includes the capability to display raw output from thermal models (such as Temperature, Heat Load, etc.) as well as derived data from the same output files (such as Sink Temperatures and Heat Flows). This data is displayed as a transient plot along with the corresponding tabular data. Furthermore, COVeR includes the capability to display heat flows between groups in a block diagram form with numerous options to control the display (e.g. show heat imbalances, conductance values, color bars, etc.). Heat Flow layouts may be saved and retrieved for use with updated output files or those from other cases. Lastly, the images may be pasted into other programs or printed as needed.

New and Advanced Features of Thermal Desktop
3:15 pm – 5:00 pm
Room 5
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, no prior experience with Thermal Desktop is 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.

Cleveland Indians Networking Event
7:05 pm

Cleveland Indians at Progressive Field
2401 Ontario St.
Cleveland, OH 44115

Attendees were given the opportunity to purchase tickets to watch the Cleveland Indians face their rivals from across the state, the Cincinnati Reds in Section 125 of the Lower Reserve seating at Progressive Field. Ticket sales were available through July 28, 2014 for $21/ticket. Members of the TFAWS committee will be in the lobby of the Hyatt Regency hotel between 6:30 pm and 6:45 pm to meet prior to walking to Progressive Field for the game. See the registration desk for more information.

Session Descriptions: Wednesday, August 6

Aerothermal Paper Session
9:15 am – 11:00 am
Room 1
Session Chairs: Karen Berger (NASA LaRC) & Jason Mishtawy (NASA MSFC)

9:15 AM	TFAWS2014-AE-01 (ITAR Session*)	"A New High Temperature Thermopile Heat Flux Sensor at AEDC" *Presenter: Stuart Coulter (Arnold Air Force Base)*
10:00 AM	TFAWS2014-A-02	"Space Shuttle Boundary Layer Transition Flight Experiment Ground Testing Overview" *Presenter: Karen Berger (NASA LaRC)*
10:30 AM	TFAWS2014-AE-03	"Langley Aerothermodynamic Labs: Testing Capabilities" *Presenter: Karen Berger (NASA LaRC)*

*Only U.S. Citizens and U.S. Resident Aliens are permitted to attend ITAR sessions. At the time of registration, attendees planning to attend an ITAR session must present the required proof of citizenship. U.S. Citizens can show proof of citizenship using a passport, birth certificate, voter's registration card, or naturalization papers and U.S. resident aliens can show proof with a resident alien card.

NX Thermal/Flow Software Training
8:00 am – 9:45 am
Room 3
Instructor: Carl Poplawsky (MAYA Simulation Technologies)

NX Thermal and Flow are powerful finite volume based thermal and CFD solvers, fully embedded in the Siemens PLM NX CAD package. You may recognize them by their former names, I-deas TMG and I-deas ESC. All pre- and post-processing is accomplished with NX Advanced Simulation, and includes the ability to define the simulation on the parametric geometry for rapid updates during design changes. This also allows for automated parameter driven optimization of the design. Choose one or both workshops, taking the user through the parameterized model definition process and performing automated parameter driven thermal and flow optimization.

ANSYS/FLUENT Software Training
8:00 am – 11:45 am
Room 4
Instructor: Parsa Zamankhan and Valerio Viti

In this session we will give short presentation on ANSYS CFD products with a focus on A&D applications and then attendances will have the opportunity to explore a variety of our advanced technologies (including Multiphase, MDM, DPM, Adjoint Solver, and Thermal FSI) through going into the workshops.

TARP and COVeR Capabilities Demonstration
8:00 am – 9:45 am
Room 5
Instructor: Hume Peabody (Thermal Modeling Solutions, LLC)

TARP is a Windows based post-processing program that creates an interface between the ASCII output from numerous thermal analysis solvers and Microsoft Excel. COVeR is a new post processing environment nearing completion to allow a user to quickly find and display nodes or groups of interest, leveraging the data structures used in TARP. This demonstration will cover the full suite of capabilities for both TARP and COVeR.

On-Orbit Thermal Environments
8:00 am – 11:45 am
Room 6
Instructor: Steve Rickman (NESC)

Spacecraft on-orbit thermal control analyses are driven by environmental heating conditions. This math-based course provides a detailed introduction to the on-orbit thermal environment. Students will gain an understanding of the factors used to derive solar flux, albedo, and planetary infrared heating and how they are applied in real analyses. Expressions for environmental heating parameters will be derived. The beta angle is explored in detail including its derivation and its effect on the on-orbit thermal environment. The course concludes with illustrative examples designed to enhance the students' insights into on-orbit environmental heating.

Femap Thermal/Flow Software Training
10:00 am – 11:45 am
Room 3
Instructor: Carl Poplawsky (MAYA Simulation Technologies)

Femap Thermal and Flow are powerful finite volume based thermal and CFD solvers, fully embedded in the Siemens Femap tool. You may recognize them by their former names, I-deas TMG and I-deas ESC. Femap is a stand-alone finite element pre-and post-processor, capable of accepting geometry from any commercially available CAD system, and supports multiple solvers including Femap Thermal and Flow. Choose one or both workshops, taking the user through the model definition process and performing thermal/flow analysis.

ANSA for Morphing and Optimization Demonstration
10:00 am – 11:45 am
Room 5
Instructors: Pravin Peddiraju & Jonathan Krueger (BETA CAE Systems)

This demonstration aims to provide the audience with a brief overview of the capabilities that are present in ANSA for Morphing & Optimization. A sample test case will be used to show features such as:

- box morphing
- direct morphing
- parameter definitions
- optimization setup

Lunch: Ten Years of Mars
12:00 pm – 1:00 pm
Junior Ballroom
Speaker: Dr. Geoffrey A. Landis (NASA GRC)

Active Thermal Paper Session II
1:15 pm – 5:00 pm
Room 1
Session Chairs: Steve Barsi (NASA GRC) & Craig Dinsmore (NASA JSC)

1:15 PM	TFAWS2014-AT-06	"Water-Based Phase Change Material Heat Exchanger Development" *Presenter: Scott Hansen (NASA JSC)*
1:45 PM	TFAWS2014-AT-07	"Launch Vehicle Avionics Passive Thermal Management" *Presenter: Bill Anderson (ACT, Inc.)*
2:15 PM	TFAWS2014-AT-08	"Spacesuit Water Membrane Evaporator, An Enhanced Evaporative Cooling System for the Advanced Extravehicular Mobility Unit Portable Life Support System" *Presenter: Grant Bue (NASA JSC)*
3:15 PM	TFAWS2014-AT-09	"Mini-Membrane Evaporator for Contingency Spacesuit Cooling" *Presenter: Janice Makinen (NASA JSC)*
3:45 PM	TFAWS2014-AT-10	"Low Cost Radiator for Fission Power Thermal Control" *Presenter: Bill Anderson (ACT, Inc.)*
4:15 PM	TFAWS2014-AT-11	"SINDA/FLUINT Stratified Tank Modeling For Cryogenic Propellant Tanks" *Presenter: Barbara Sakowski (NASA GRC)*

Generalized Fluid System Simulation Program (GFSSP) Software Training
1:15 pm – 5:00 pm
Room 3
Instructor: André LeClair (NASA MSFC)

GFSSP is a general-purpose computer program for analyzing steady-state and time-dependent flow rate, pressure, temperature, and concentrations in a complex flow network. The program is capable of modeling phase changes, 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 half-day course will teach the use of the Graphical User Interface to develop, run, and interpret the results of thermo-fluid system models. Students will build two models as a group activity, and have the opportunity to work one or more hands-on tutorials.

ANSA for Morphing & Optimization Software Training
1:15 pm – 5:00 pm
Room 4
Instructors: Pravin Peddiraju & Jonathan Krueger (BETA CAE Systems)

The purpose of this short course is to provide attendees with hands on exposure to the morphing tools available inside ANSA. A step-by-step tutorial will guide attendees through preparing the morphing domains and setting up the optimization problem.

Fully Implicit Ablation Thermochemistry (FIAT) Training Course
1:15 pm – 5:00 pm
Room 5
Instructor: Frank Milos (NASA ARC)

FIAT is widely used by NASA and industry for one-dimensional time-accurate thermal analysis and sizing of thermal protection systems. This course begins with comprehensive FIAT training that describes the theory, equations, numerical procedures, input and output, and sample problems. Then, depending on interests of the attendees, Dr. Milos will discuss approaches to perform specific types of analyses.

Thermal Testing Course
1:15 pm – 5:00 pm
Room 6
Instructor: Eric Grob (NASA GSFC)

Thermal testing for space missions is one of the most effective, and most costly, environmental tests. This instructor-led discussion will provide background on why thermal testing is performed, and how it has evolved since spaceflight began. The course includes discussion of various types of environment simulation techniques, different thermal test philosophies in the industry, test set-up, thermal balance, environmental stress screening cycles, and pre- & post-test analysis and documentation. The course will include examples from current/past projects, and interactive discussions are encouraged.

TFAWS 2014 Keynote Banquet
6:00 pm – 9:00 pm

The City Club of Cleveland
850 Euclid Ave
Cleveland, OH 44144

The TFAWS 2014 Keynote Banquet will be held on Wednesday, August 6, from 6 pm to 9 pm at the prestigious City Club of Cleveland. The Keynote Banquet will feature Colonel Richard H. Graham, USAF (retired), who will take attendees on a thrilling journey into the history of the engineering team that created the world's fastest air-breathing manned aircraft, the SR-71 Blackbird. In addition to Colonel Graham's Keynote Address, the banquet will feature delicious entrées and dessert along with a cash bar and the chance to further network with peers and colleagues.

The City Club of Cleveland is located at the Southwest corner of E. 9th & Euclid on the second floor of the City Club Building. The City Club Building is within convenient walking distance from the Hyatt Regency Hotel and the Cleveland Convention Center, and provides the perfect setting for the 25th Anniversary celebration of the Thermal and Fluids Analysis Workshop. Don't miss out on this once-in-a-lifetime event! Tickets for the Keynote Banquet were available at $44 per person. You must have purchased a ticket by July 30, 2014 in order to attend the banquet. Questions regarding the event can be directed to the Registration Desk. Dress is business casual.

Session Descriptions: Thursday, August 7

Passive Thermal Paper Session II
8:00 am – 11:00 am
Room 1
Session Chairs: Laurie Carrillo (NASA JSC) & A.J. Mastropietro (NASA JPL)

8:00 AM	TFAWS2014-PT-06	"Thermal interface materials and challenges faced by thermal interface material suppliers" *Presenter: Jason Strader (Laird)*
8:30 AM	TFAWS2014-PT -07	"LTCS (Laser Thermal Control System) test supporting the improvement of DeCoM (Deepak Condenser Model)" *Presenter: Deepak Patel (NASA GSFC)*
9:00 AM	TFAWS2014-PT-08	"Using SpaceClaim/TD Direct for Modeling Components with Complex Geometries for the Thermal Desktop-based Advanced Stirling Radioisotope Generator Model" *Presenter: William Fabanich (NASA GRC)*
9:30 AM	TFAWS2014-PT-09	"Cube Flux Method to Generate Spacecraft Thermal Environments" *Presenter: Siraj Jalali (Oceaneering)*
10:30 AM	TFAWS2014-PT-11	"Passive Thermal Design approach for the Space Communications and Navigation (SCaN) experiment on the International Space Station (ISS)" *Presenter: James Yuko (NASA GRC)*

Non-Grey Body Heat Transfer Course
8:00 am – 11:45 am
Room 3
Instructor: Douglas Bell (CR Tech)

This session will provide an overview of non-grey radiation heat transfer, the common misconceptions and pitfalls, and an introduction to performing non-grey body radiation analyses in RadCAD. The user should attend the Introduction to RadCAD session or be familiar with Thermal Desktop prior to attending.

Advanced TSS Software Training
8:00 am – 5:00 pm
Room 4
Instructors: Joe Lepore & Joe Clay (Spacedesign Corp.)

This hands-on class will demonstrate more TSS features and modeling techniques. Topics include: Radiation analysis of CAD surfaces using STEP and IGES Translators, further use of the SindaWin application, Geometry model validation, building models with Symbols, distributed processing, managing Boolean surfaces and chains, B-splines, using Booleans with Radk/Heatrate, adjusting conductor values, using the Mesh and FEM applications, and SATSTRAN. Topics of specific interest to users will be discussed. Examples 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.

MSC Apex Demonstration
8:00 am – 9:45 am
Room 5
Instructor: Larry Pearce (MSC Software)

MSC Software will present their new product, MSC Apex. MSC Apex is a new simulation analysis platform that has just been released in 2014. Come learn how to create meshes 10x faster than the tools you are using today. Learn how to develop solver-validated models to ensure mesh quality before submitting analyses. And learn about the future roadmap of this new and exciting product!

MMOD Protection and Degradation Effects for Thermal Control Systems
8:00 am – 11:45 am
Room 6
Instructor: Eric Christiansen (NASA JSC)

Micrometeoroid and Orbital Debris (MMOD) impacts represent a significant risk for crewed and non-crewed spacecraft, particularly for long-duration space missions such as the International Space Station (ISS). This course will describe the current micrometeoroid and orbital debris environment models, the effects of high-velocity MMOD impacts on spacecraft surfaces particularly radiators and thermal control coatings, and how spacecraft are typically protected from MMOD impacts. The MMOD risk assessment process will be described which relies on analysis supported by hypervelocity impact tests. Course participants will be able to examine impacted samples of spacecraft hardware. MMOD damage that has been sustained by ISS hardware and methods employed on ISS to reduce the consequences of MMOD impacts will be discussed.

NX Thermal/Flow Demonstration
10:00 am – 10:50 am
Room 5
Instructor: Carl Poplawsky (MAYA Simulation Technologies)

NX Thermal and Flow are powerful finite volume based thermal and CFD solvers, fully embedded in the Siemens PLM NX CAD package. You may recognize them by their former names, I-deas TMG and I-deas ESC. All pre- and post-processing is accomplished with NX Advanced Simulation, and includes the ability to define the simulation on the parametric geometry for rapid updates during design changes. This also allows for automated parameter driven optimization of the design. Choose one or both workshops, taking the user through the parameterized model definition process and performing automated parameter driven thermal and flow optimization.

Generalized Fluid System Simulation Program (GFSSP) Demonstration
10:55 am – 11:45 am
Room 5
Instructor: André LeClair (NASA MSFC)

GFSSP is a general-purpose computer program for analyzing steady-state and time-dependent flow rate, pressure, temperature, and concentrations in a complex flow network. The program is capable of modeling phase changes, 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.

Lunch: Optimized Integrated Multidisciplinary Systems (OPTIMUS)
12:00 pm – 1:00 pm
Junior Ballroom
Speaker: Steven M. Iden (NASA GRC)

Site Tour of NASA Glenn Research Center at Lewis Field (Group B)
1:15 pm – 5:00 pm

Please meet in front of the Lakeview Ave. entrance of the Cleveland Convention Center by 1:00 pm to ensure that you do not miss the bus departure time. See pages 29 and 30 for more information.

Interdisciplinary Paper Session
1:15 pm – 3:00 pm
Room 1
Session Chairs: Richard Wear (NASA SSC) & Xiaoyen Wang (NASA GRC)

1:15 PM	TFAWS2014-I-01	"SRTMV-N2 Plume Impingement Test Panel Thermal Analysis" *Presenter: Vincent Cuda (NASA MSSC)*
1:45 PM	TFAWS2014-I-02	"Flow characteristics of a strut injector for scramjets: numerical and experimental results" *Presenter: Valerio Viti (ANSYS, Inc.)*
2:15 PM	TFAWS2014-I-04	"Thermal Acoustic Oscillation: Causes, Detection, Analysis, and Prevention" *Presenter: Robert Christie (NASA GRC)*

Thermal and Fluid Flow Analysis With COMSOL
1:15 pm – 5:00 pm
Room 3
Instructors: Walter Frei & Yeswanth Rao (COMSOL Multiphysics)

Discover the power of COMSOL Multiphysics for thermal and fluid flow analysis in this workshop. Learn to model transport phenomena such as conduction of heat through solids, convection by moving fluids and radiation of heat via infrared. Also, find out how to couple these analyses with one another and how they interact other physics such as structural mechanics (thermal stresses), electromagnetics (EM heating) etc. The motto of this workshop is "learn-by-doing". There will be an opportunity to try COMSOL with the help of the instructor. The goal is to teach you the skills needed to model problems in COMSOL Multiphysics. Who should attend? Anyone interested in simulating and optimizing engineering phenomena based on PDEs, such as structural mechanics, heat transfer, electromagnetics, fluid flow, etc.

SpaceClaim Engineer 2012+: Reconstructing Geometry From STL Data for Thermal Analysis
1:15 pm – 2:00 pm
Room 5
Instructor: Roman Walsh (SpaceClaim Corp.)

Many people use SpaceClaim for simplifying models prior to analysis, creating geometry from scratch, or using it to prepare fluid domains. But what people may not realize is that SpaceClaim is also a fantastic tool for reverse engineering data they might get from scanners, structural optimization software, or as a mesh export. SpaceClaim can take these mostly unusable STL files and quickly generate robust geometry that works great for further thermal or fluid analysis with any tool on the market. Come learn first-hand how SpaceClaim can be your Swiss army knife for all your geometry needs around analysis.

Two-Phase Flow and Heat Transfer
1:15 pm – 5:00 pm
Room 6
Instructors: Dr. Henry Nahra & Dr. Mohammad M. Hasan (NASA GRC)

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.

TFAWS Delegates Meeting – Invite Only
4:00 pm – 6:00 pm
Room 5

Nautica Queen Dining and Sightseeing Sunset Cruise
7:00 pm – 9:30 pm (must board ship by 6:45 pm)

The Nautica Queen Cruise Ship
1153 Main Ave
Cleveland, OH 44113

On Thursday, August 7, 2014, TFAWS attendees and guests are invited to a dinner and sightseeing lakefront & river cruise on the Nautica Queen. The Nautica Queen offers a full, all-you-can-eat banquet dinner and stunning views of downtown Cleveland as it cruises on the calm shores of Lake Erie and the Cuyahoga River for a total price of $35.23 per person. Ticketing is based on availability, but may still be available. To purchase tickets, phone the Nautica Queen staff at (216) 696–8888 [toll free: (800) 837–0604]. You must mention the confirmation number 11378-5 to reserve seats with the TFAWS group. Orders may need to reference Bill Fabanich.

Boarding will begin at 6:00 pm (no later than 6:45 pm) and will set sail promptly at 7:00 pm. It will return to the dock at 9:30 pm. A cash bar will also be available. Please note that the dock for the Nautica Queen is located a very short drive away from the hotel and conference site. The TFAWS committee will be happy to assist in arranging carpooling and other transportation options at the registration desk. Dress is business casual – no jeans or tennis shoes, please.

Lunchtime Speakers

Monday Luncheon Speaker: Mr. Steven L. Rickman, NESC
History of Spacecraft Thermal Analysis, Then and Now

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.

He began his NASA career, just prior to his nineteenth birthday, in 1981 as a cooperative education student at the Goddard Space Flight Center focusing on thermal-vacuum and structural dynamic testing. He transferred to the Johnson Space Center in 1982 and was hired into the JSC Thermal Branch upon graduation in 1985. Steve was named Deputy Chief of the Thermal Branch in 1998 and Chief of the Thermal Design Branch in 2002. He and his branch provided thermal technical expertise to the Columbia accident investigation. He served as the NASA lead for the Flight-Day-Two Object Radar Team and worked with the U.S. Air Force on this facet of the investigation. In 2006, he led the Tile Overlay Repair Development Team, focused on developing a repair for Space Shuttle tile damage.

Steve's primary interest has been in the area of passive thermal control of orbiting spacecraft. He's served on numerous design teams including the TransHab inflatable module project as lead environments engineer and lead thermal analyst. As the NASA technical manager, he led the development of the Thermal Synthesizer System (TSS) analysis tool suite. He was the thermal design engineer for the Inter-Mars Tissue Equivalent Proportional Counter, the ISS Extravehicular Charged Particle Directional Spectrometer and the Mars Odyssey 2001 Martian Radiation Environment Experiment. He also developed concurrent engineering techniques for representing thermal protection systems in spacecraft thermo-mechanical stress models. He co-developed a general-purpose on-orbit thermal environments tool that was used extensively during the STS 35 ASTRO-1 mission.

Steve has authored or co-authored 14 technical papers and conference presentations including public testimony given with the U.S. Air Force to the Columbia Accident Investigation Board. He also 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. He has received numerous mentoring, Group Achievement, Tech Brief and Space Act Awards and has been honored with the NASA Exceptional Achievement Medal. In autumn 2011, he was named an Adjunct Professor of Mechanical Engineering and Materials Science at Rice University.

Steve 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.

Tuesday Luncheon Speaker: Ms. Mary F. Wadel, NASA
We Freeze To Please – Aircraft Icing

Ms. Wadel's career has spanned over 25 years at the NASA Glenn Research Center. She holds a B.S. in Aerospace Engineering and a M.S. in Aerospace and Mechanical Engineering. Her work experience has covered a variety of technology areas such as rocket propulsion concepts and systems, cryogenic fluid management, aircraft icing, fixed wing aircraft, and experimental testing in wind tunnels. Ms. Wadel began her career doing experimental research and has since held several project management leadership positions in key Aeronautics and Space technology development programs. Currently, Ms. Wadel is Chief of the Icing Branch.

Wednesday Luncheon Speaker: Dr. Geoffrey A. Landis, NASA
Ten Years of Mars

Dr. Geoffrey A. Landis is a scientist at the NASA John Glenn Research Center. He was a member of the Mars Pathfinder scientific team, where he analyzed solar energy and dust on Mars, and is currently a member of the science team for the Mars Exploration Rovers. In addition to his work on Mars, he works on developing advanced concepts for spaceflight. He was one of the first fellows of the NASA Institute of Advanced Concepts, where he worked on analyzing new concepts for laser-pushed lightsails. He is currently working on future missions including the Solar Probe Plus, a spacecraft to probe the outer corona of the sun, design concepts for telerobotic missions to Mars, Venus, and the asteroids, and development of technology for in-situ resource utilization for the moon and Mars. He has published four hundred scientific papers in the fields of photovoltaics and astronautics, and holds seven patents. Dr. Landis is also a Hugo- and Nebula- award winning science fiction writer. His novel Mars Crossing won the Locus award for best first novel. More information can be found on his web page at http://www.geoffreylandis.com/.

Thursday Luncheon Speaker: Mr. Steven M. Iden, Air Force Research Laboratory
Optimized Integrated Multidisciplinary Systems (OPTIMUS)

Mr. Steven M. Iden is the Optimized Integrated Multidisciplinary Systems (OPTIMUS) Program Manager for the USAF Aerospace Vehicles Division of the Air Force Research Laboratory Aerospace Systems Directorate. He is a member of Institute of Electrical and Electronics Engineers (IEEE), SAE, and Tau Beta Pi. Mr. Iden has a B.S., M.S. in Electrical Engineering from the University of Dayton and has 30 years of experience in the aerospace industry. He joined AFRL from Lockheed Martin Skunk Works, where he led the F-35 vehicle systems improvements and derivatives team.

More efficient and capable high performance aircraft require highly integrated designs with energy balance considered at conceptual design. Propulsion, power, and thermal challenges require the knowledge and integration of complex systems early in the design. The OPTIMUS program was established by AFRL to bring new disciplines to the Multidisciplinary Design Optimization to address these challenges by developing new methods that merge conceptual and preliminary design.

Keynote Speaker

Wednesday Keynote Banquet

Colonel Richard H. Graham, USAF (retired)
The SR-71 Blackbird – An Engineering Marvel

Colonel Richard H. Graham (retired) started his flying career as a teenager, soloing out at age 17. He entered the Air Force in 1964 and flew 210 combat missions in Vietnam flying the F-4 Phantom. He then flew the SR-71 Blackbird for seven years on operational reconnaissance missions. He was Squadron Commander of the SR-71 unit in 1980 and eventually became the Wing Commander at Beale AFB, California, where he flew the SR-71, U-2, KC-135, and T-38 aircraft. Among his awards and decorations includes 3 Legion of Merit Awards, 4 Distinguished Flying Cross medals and 19 Air Medals. After 25 years in the Air Force, Colonel Graham flew 13 years for American Airlines. He retired in August 2002 as a Captain on the MD-80 aircraft. He has accumulated over 14,000 flying hours.

He now keeps busy as an author, speaker, aviation consultant, flight instructor and Civil Air Patrol pilot. Colonel Graham has written four books on the SR-71 and will be available to autograph and purchase at the end of the presentation. He was the 1999 recipient of the University of Nebraska's William F. Shea Award for his distinguished contribution to aviation. In 2005 he received the Kelly Johnson Award for his lifetime achievements to the Blackbird program. He received the 2013 Congressional Veterans Commendation in November from Congressman Sam Johnson. He is currently a Distinguished Lecturer for the American Institute of Aeronautics and Astronautics (AIAA). He serves on the Leadership Council at the Frontiers of Flight Museum in Dallas and on the International Advisory Board of Directors at the Flight of the Phoenix Aviation Museum in Gilmer, Texas. He is also a member of the FAAST team for the FAA.

The world's fastest and highest flying aircraft was conceived as early as 1958 by the renowned aircraft engineer, Kelly Johnson. The gigantic leap in technology he and his engineers had to overcome at the Lockheed Skunk Works was phenomenal. Built in total secrecy, the first Blackbird flew on April 26, 1962. The Blackbird's only purpose was to gather highly classified intelligence on hostile countries around the world. Flying at Mach 3+ speeds and cruising at over 85,000 feet, the SR-71 could survey over 100,000 square miles every hour, gathering in millions of bits of intelligence. When cruising at over 2,100 mph, with skin friction temperatures reaching 700 degrees Fahrenheit, the SR-71 performed at its very best! Colonel Graham's presentation will discuss the evolution of the SR-71 and some of the major hurdles Kelly Johnson and his band of engineers had to overcome in order to reach Mach 3+ speeds.

NASA Glenn Research Center Site Tours at Lewis Field

Site tours of NASA Glenn Research Center at Lewis Field in Cleveland, OH will be available directly following lunch on the afternoons of Tuesday, August 5, and Thursday, August 7. Each tour group will be limited to 50 people on a first-come, first-served basis. Both tours will visit the same facilities, providing attendees with access to four of NASA's premier test facilities.

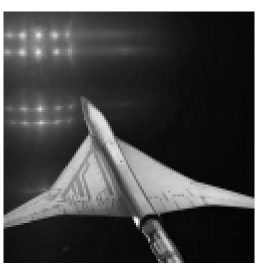
Icing Research Tunnel (IRT)

The Icing Research Tunnel (IRT) is one of the world's largest refrigerated wind tunnels dedicated to study aircraft icing. In this facility, natural icing conditions are duplicated to test the effects of in-flight icing on actual aircraft components and models of aircraft, including helicopters. A variety of tests are performed in the IRT including fundamental studies of icing physics, icing prediction validation, and ice protection system development and certification. These tests successfully reduce flight test hours for ice detection instrumentation and ice protection systems certification.

Zero Gravity Research Facility

The Zero Gravity Research Facility is NASA's premier facility for ground based microgravity research, and the largest facility of its kind in the World. Operational since 1966, it is one of two drop towers located at the NASA Glenn Research Center. It was originally designed and built during the space race era of the 1960s to support research and development of space flight components and fluid systems, in a weightless or microgravity environment. The Zero-G facility provides researchers with a microgravity environment for a duration of 5.18 seconds by allowing the experiment hardware to free fall a distance of 432 feet (132 m). The facility is used by investigators from around the world to study the effects of microgravity on physical phenomena such as combustion, fluid physics, biotechnology, and materials science, as well as to develop and test experiment hardware designed for flight aboard the International Space Station.

10- by 10-Foot Abe Silverstein Supersonic Wind Tunnel



Throughout its history, the 10- by 10-Foot Supersonic Wind Tunnel (10×10 SWT) has made valuable contributions to the advancement of fundamental supersonic propulsion technology. Researchers have used the facility to aid in the development of the Atlas-Centaur, Saturn, and Atlas-Agena-class launch vehicles, and for such vehicle-focused research programs as the High-Speed Civil Transport, the National AeroSpace Plane, and the Joint Strike Fighter. The test section is large enough to accommodate large-scale models and full-size aircraft components. The 10×10 SWT was specifically designed to test supersonic propulsion components such as inlets, nozzles, and full-scale jet and rocket engines. It also has been effectively utilized for force balances models and spacecraft reentry decelerator testing.

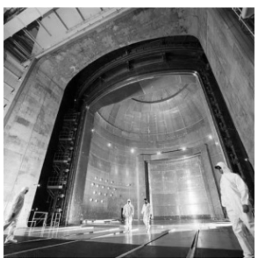
Simulated Lunar Operations (SLOPE) Facility

NASA Glenn Research Center is improving the mobility of lunar rovers in one of the center's newest labs, the Simulated Lunar Operations (SLOPE) facility. The facility is home to a 60-foot long by 20-foot wide sandpit filled with simulated lunar soil and a lunar rover test bed. One 20-foot end of the sandpit can rise to replicate the slopes in moon craters. This research will help NASA develop rovers capable of traveling long distances during future human and robotic missions to the moon and beyond.

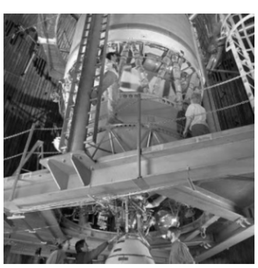
NASA Glenn Research Center Site Tours at Plum Brook Station

Site tours of NASA Glenn Research Center's Plum Brook Station facility in Sandusky, OH will be available on the morning of Friday, August 8. The tour group will be limited to 50 people on a first-come, first-served basis. The Plum Brook Station tour will feature two of the most unique test facilities in the world.

Space Power Facility (SPF)



The Space Power Facility (SPF) houses the world's largest and most powerful space environment simulation facilities. The **Space Simulation Vacuum Chamber** is the world's largest measuring 100 ft. in diameter by 122 ft. high, and was designed and constructed to test both nuclear and non-nuclear space hardware in a simulated Low-Earth-Orbiting environment. Although the facility was designed for testing nuclear hardware, only non-nuclear tests have been performed throughout its history. Some of the test programs that have been performed at the facility include high-energy experiments, full-scale rocket-fairing separation tests, Mars Lander system tests, deployable Solar Sail tests and International Space Station hardware tests. The **Reverberant Acoustic Test Facility (RATF)** is the world's most powerful spacecraft acoustic test chamber, with a 2,860 m^3 (101,189 ft^3) reverberant acoustic chamber capable of achieving an empty-chamber acoustic overall sound pressure level (OASPL) of 163 dB. **The Mechanical Vibration Facility (MVF)** is the world's highest capacity and most powerful spacecraft shaker system, and its 3-axis, 6 degrees of freedom, servo-hydraulic, sinusoidal base-shake vibration system is located within the same Vibroacoustic Highbay as the RATF on the West side of the vacuum chamber.



Spacecraft Propulsion Research Facility (B-2)

NASA's Spacecraft Propulsion Research Facility (B-2) is the world's only facility capable of testing full-scale upper-stage launch vehicles and rocket engines under simulated high-altitude conditions. The engine or vehicle can be exposed in the 38 ft. in diameter by 55 ft. tall test volume for indefinite periods to low ambient pressures, low-background temperatures, and dynamic solar heating, simulating the environment the hardware will encounter during orbital or interplanetary travel. Vehicle engines producing up to 400,000-lb of thrust can be fired for either single or multiple burn missions, utilizing either cryogenic or storable fuels or oxidizers. Engine exhaust conditions can be controlled to simulate a launch ascent profile. In addition, conditions can be maintained before, during, and after the test firing. B-2 offers a complete "test-as-you-fly" environment to thoroughly ground test flight hardware and reduce the likelihood of costly flight failures. In 1998, tests of the Boeing Delta III cryogenic upperstage were successfully conducted in the B-2 facility.

Paper Abstracts: Active Thermal

Active Thermal Paper Session I

TFAWS2014-AT-01

CFD Analysis of Thermal Control System Using NX Thermal & Flow

Craig Fortier, NASA KSC
Michael Harris, NASA KSC
Stephen McConnell, NASA KSC

Abstract
The Thermal Control Subsystem (TCS) is a key part of the Advanced Plant Habitat (APH) for the International Space Station (ISS). The purpose of this subsystem is to provide thermal control, mainly cooling, to the other APH subsystems. One of these subsystems, the Environmental Control Subsystem (ECS), controls the temperature and humidity of the growth chamber (GC) air to optimize the growth of plants in the habitat. The TCS provides thermal control to the ECS with three cold plates, which use Thermal Electric Coolers (TECs) to heat or cool water as needed to control the air temperature in the ECS system. In order to optimize the TCS design, pressure drop and heat transfer analyses were necessary.

The analysis for this system was performed in Siemens NX Thermal/Flow software (Version 8.5). NX Thermal/Flow has the ability to perform 1D or 3D flow solutions. The 1D flow solver can be used to represent simple geometries, such as pipes and tubes. The 1D flow method also has the ability to simulate either fluid only or fluid and wall regions. The 3D flow solver is similar to other Computational Fluid Dynamic (CFD) software.

TCS performance was analyzed using both the 1D and 3D solvers. Each method produced different results, which will be evaluated and discussed.

TFAWS2014-AT-02

Thermal Analysis of Cryogenic Hydrogen Liquid Separator

Jared Congiardo, NASA KSC
Craig Fortier, NASA KSC
Michael Harris, NASA KSC

Abstract
Engine conditioning for the Space Launch System core stage requires a high liquid hydrogen flowrate through the engines during terminal count. Analysis of the performance of the ground-side portion of the hydrogen bleed system indicated a strong possibility that this liquid hydrogen flow would not completely vaporize prior to reaching the facility flare stack. This would exceed the design capability of the flare stack.

In order to protect the flare stack while meeting SLS vehicle requirements, a cryogenic hydrogen liquid separator is being developed to detain the bulk of the liquid hydrogen flowing from the vehicle. The detained liquid hydrogen will be removed via either drain or boiloff following either liftoff or scrub. Such separators are common in petroleum industry processes in order to extract entrained liquid droplets from a gas stream. Removal of the gas component of a saturated liquid flow, particularly of a cryogen, is much less common.

Thermal Desktop analysis has been performed to ensure that the separator will operate as intended without adversely affecting vehicle interface conditions. Volume of Fluids (VOF) CFD analysis has also been performed in order to adequately capture multidimensional effects.

TFAWS2014-AT-03

Application of CFD to Simulate Water Droplet Impingements for Aircraft Icing Analysis

Nili Bachchan, Metacomp Technologies, Inc.
Inchul Kim, Metacomp Technologies, Inc.
Oshin Peroomian, Metacomp Technologies, Inc.
Sukumar Chakravarthy, Metacomp Technologies, Inc.
Daniel Martins da Silva, Embraer Aircraft Corp.

Abstract
In the design of ice-protection systems, numerical approaches are employed to support experimental testing over a range of aircraft flight conditions and configurations. For icing and impingement problems, an important parameter is the collection efficiency. The collection efficiency β, is defined as the ratio of the mass flow rate of the impinging droplets on a surface to the mass flow rate of the freestream. Accuracy in the prediction of collection efficiency is a preliminary step in icing analysis and the determination of ice accretion on aircraft surfaces. A collection efficiency model is implemented into the Eulerian Dispersed Phase (EDP) module in CFD++, the commercial CFD code from Metacomp Technologies, and is used to study collection efficiencies for small and large droplet conditions. An Eulerian-Eulerian approach is employed which solves the differential transport equations for each of the continuous and dispersed phases simultaneously. Equal and opposite source terms are used to accurately model the momentum and energy transfer between the two phases. Validation cases are presented for two and three dimensional bodies including engine nacelles, airfoils and glaze ice shapes, for which experimental impingement data has been obtained at the Icing Research Tunnel at NASA. Applications to icing clouds with median volumetric diameters greater than 50 microns which fall outside the Appendix C envelope have also been studied. Ice accretion due to Supercooled Large Droplets (SLD) can cause severe aircraft performance degradation. The numerical prediction of large droplet impingements require an extended numerical model to account for additional droplet-wall interaction regimes. Recently, the numerical model in CFD++ has been extended to account for droplet rebound and splash mechanisms, to improve the prediction of droplet impingement behavior within the SLD regime. Predictions of collection efficiencies with SLD modeling are presented for airfoils and glaze ice shapes for median volumetric diameter conditions up to 236 microns. CFD simulations have been carried out with the extended numerical model to include the effects of bouncing and splashing for SLDs. The results show

that the maximum values of the collection efficiency peaks are slightly reduced in all droplet MVD cases. These peak values were over-predicted without the SLD model for the larger droplet impingement cases. Improved predictions are obtained on the lower and upper airfoil surfaces away from the leading edge with the SLD model, compared to without the model. The close agreement with experimental data near the impingement limits is attributed to the substantial mass loss from droplet bouncing. For the five glaze ice shapes simulated with SLD modeling, the predictions show that slightly higher peak values were obtained from CFD compared to experimental data. The collection efficiency peak values near the airfoil leading edges are significantly reduced with SLD modeling due to the mass loss. The largest discrepancies are found in the horn region of the ice shapes, however, the trends in these regions are similar to experiment in most cases. Away from the main impingement zone, the SLD model correctly predicts experimental trends with nearly identical levels compared to experimental data obtained by Papadakis et al.

TFAWS2014-AT-04

One Dimensional Analysis Model of a Condensing Spray Chamber Including Rocket Exhaust Using SINDA/FLUINT and CEA

Barbara Sakowski, NASA GRC
Daryl Edwards, NASA GRC

Abstract
Modeling droplet condensation via CFD codes can be very tedious, time consuming, and inaccurate. CFD codes may be tedious and time consuming in terms of using Lagrangian particle tracking approaches or particle sizing bins. Also since many codes ignore conduction through the droplet and or the degrading effect of heat and mass transfer if noncondensible species are present, the solutions may be inaccurate. The modeling of a condensing spray chamber where the significant size of the water droplets and the time and distance these droplets take to fall, can make the effect of droplet conduction a physical factor that needs to be considered in the model. Furthermore the presence of even a relatively small amount of noncondensible has been shown to reduce the amount of condensation [Ref. 1]. It is desirable then to create a modeling tool that addresses these issues. The path taken to create such a tool is illustrated. The application of this tool and subsequent results are based on the spray chamber in the Spacecraft Propulsion Research Facility (B2) located at NASA's Plum Brook Station that tested an RL-10 engine. The platform upon which the condensation physics is modeled is SINDA/FLUINT. The use of SINDA/FLUINT enables the ability to model various aspects of the entire testing facility, including the rocket exhaust duct flow and heat transfer to the exhaust duct wall. The ejector pumping system of the spray chamber is also easily implemented via SINDA/FLUINT. The goal is to create a transient one dimensional flow and heat transfer model beginning at the rocket, continuing through the condensing spray chamber, and finally ending with the ejector pumping system. However the model of the condensing spray chamber may be run independently of the rocket and ejector systems detail, with only appropriate mass flow boundary conditions placed at the entrance and exit of the condensing spray chamber model. The model of the condensing spray chamber takes into account droplet conduction as well as the degrading effect of mass and heat transfer due to the presence of noncondensible. The one dimension model of the condensing spray chamber makes no presupposition on the pressure

profile within the chamber, allowing the implemented droplet physics of heat and mass transfer coupled to the SINDA/FLUINT solver to determine a transient pressure profile of the condensing spray chamber. Model results compare well to the RL-10 engine pressure test data.

TFAWS2014-AT-05

Different Kinds of Heat Pipes

William G. Anderson, Advanced Cooling Technologies

Abstract

Most people in the spacecraft thermal control community are familiar with Constant Conductance Heat Pipes (CCHPs) to transport heat from point A to Point B. Similarly, Variable Conductance Heat Pipes (VCHPs) are used to maintain the heat pipe evaporator at a relatively constant temperature. This presentation will briefly review the standard uses for CCHPs and VCHPs, and then discuss other heat pipe types and applications. The presentation will include:

- Standard Heat Pipes (CCHPs), which act as a thermal superconductor
    - Aluminum/ammonia grooved heat pipes
    - Copper/water and copper/methanol heat pipes
- Annular Heat Pipes, which have an inner cavity and are highly isothermal
- Variable Conductance Heat Pipes (VCHPs), which have a non-condensable gas loading to help maintain the evaporator temperature under changing conditions
    - VCHPs for Passively Controlling Temperature
    - VCHPs for Over-Temperature Protection
    - VCHPs for Variable Thermal Links
    - Gas Loaded (Variable Conductance) Heat Pipes for Start-Up from a Frozen State
- Pressure Controlled Heat Pipes (PCHPs), a form of VCHP where the reservoir size or gas loading can be changed
    - PCHPs for Precise Temperature Control
    - PCHPs for High Temperature Power Switching
- Vapor Chambers, which allow heat flux transformation, and heat spreading in two dimensions
- High Conductivity Plates, which have heat pipes embedded in plates to improve the effective thermal conductivity to 500-1200 W/m K
- Heat Pipe Heat Exchangers
    - VCHP Heat Exchangers
- Diode Heat Pipes, which allow heat flow in only one direction
    - Liquid Trap Diode Heat Pipes
    - Vapor Trap Diode Heat Pipes
- Thermosyphons, which are gravity aided heat pipes
    - Loop Thermosyphons, a thermosyphon variant with different flow paths for the vapor and liquid
- Rotating Heat Pipes, where the centrifugal forces generated in a rotating system return the fluid, rather than relying on a wick
    - Rotating shafts with multiple heat pipes embedded in a rotating shaft, allowing higher performance than a single rotating heat pipe

Active Thermal Paper Session II

TFAWS2014-AT-06

Water Based Phase Change Material Heat Exchanger Development

Scott Hansen, NASA JSC
Rubik B Sheth, NASA JSC
Matt Atwell, University of Texas
Ann Cheek, University of Houston
Muskan Agarwal, University of Houston
Steven Hong, University of Houston
Aashini Patel, University of Houston
Lisa Nguyen, University of Houston
Luciano, Pasado, University of Houston

Abstract
In a cyclical heat load environment such as low Lunar orbit, a spacecraft's radiators are not sized to reject the full heat load requirement. Traditionally, a supplemental heat rejection device (SHReD) such as an evaporator or sublimator is used to act as a "topper" to meet the additional heat rejection demands. Utilizing a Phase Change Material (PCM) heat exchanger (HX) as a SHReD provides an attractive alternative to evaporators and sublimators as PCM HXs do not use a consumable, thereby leading to reduced launch mass and volume requirements. Studies conducted in this paper investigate utilizing water's high latent heat of formation as a PCM, as opposed to traditional waxes, and corresponding complications surrounding freezing water in an enclosed volume. Work highlighted in this study is primarily visual and includes understanding ice formation, freeze front propagation, and the solidification process of water/ice. Various test coupons were constructed of copper to emulate the interstitial pin configuration (to aid in conduction) of the proposed water PCM HX design. Construction of a prototypic HX was also completed in which a flexible bladder material and interstitial pin configurations were tested. Additionally, a microgravity flight was conducted where three copper test articles were frozen continuously during microgravity and 2-g periods and individual water droplets were frozen during microgravity. Future direction is also suggested for future bladder PCM HX development.

TFAWS2014-AT-07

Launch Vehicle Avionics Passive Thermal Management

Cameron Corday, Advanced Cooling Technologies
Mike DeChristopher, Advanced Cooling Technologies
John R. Hartenstine, Advanced Cooling Technologies
Taylor Maxwell, Advanced Cooling Technologies
Carl Schwendeman, Advanced Cooling Technologies
Calin Tarau, Advanced Cooling Technologies
William G. Anderson, Advanced Cooling Technologies

Abstract

A passive thermal management system was developed to cool avionics on a launch vehicle, with three different thermal modes:

1. Cooling for avionics while on ground prior to launch (indefinitely)
2. Cooling for avionics during launch (~10min)
3. Cooling on-orbit (indefinitely)

In pre-launch a nitrogen purge duct serves as the heat sink (~19.4°C) for the thermal control device. The purge duct is located above the avionics, and along with the passive thermal system, must maintain the avionics within a safe operating temperature range (-6.6 to 25.5°C) while on the ground. At lift-off the nitrogen purge ceases. Potential thermal solutions for ascent period of ~10 minutes include: Phase Change Material (PCM), Hydride Thermal Storage, Launch Vehicle Skin and the Fuel. Hydride Thermal Storage cannot be used due to vented gas, the launch vehicle skin cannot be used due to skin structure, and the fuel cannot be used, which leaves PCM as the best thermal solution during ascent. While on-orbit the electronics radiate to space using an external radiator. Fuel was considered, but is not feasible as a long term heat rejection solution.

TFAWS2014-AT-08

Spacesuit Water Membrane Evaporator, An Enhanced Evaporative Cooling System for the Advanced Extravehicular Mobility Unit Portable Life Support System

Grant Bue, NASA JSC
Janice, V. Makinem, NASA JSC
Sean Miller, NASA JSC
Colin Campbell, NASA JSC
Bill Lynch, Jacobs Engineering
Matt Vogel, Jacobs Engineering
Jesse Craft, Jacobs Engineering
Robert Wilkes, Jacobs Engineering
Eric Kuehnel, Jacobs Engineering

Abstract

Development of the Advanced Extravehicular Mobility Unit (AEMU) portable life support subsystem (PLSS) is currently under way at NASA Johnson Space Center. The AEMU PLSS features a new evaporative cooling system, the Generation 4 Spacesuit Water Membrane

Evaporator (Gen4 SWME). The SWME offers several advantages when compared with prior crewmember cooling technologies, including the ability to reject heat at increased atmospheric pressures, reduced loop infrastructure, and higher tolerance to fouling. Like its predecessors, Gen4 SWME provides nominal crew member and electronics cooling by flowing water through porous hollow fibers. Water vapor escapes through the hollow fiber pores, thereby cooling the liquid water that remains inside of the fibers. This cooled water is then recirculated to remove heat from the crew member and PLSS electronics. Test results from the backup cooling system which is based on a similar design and the subject of a companion paper, suggested that further volume reductions could be achieved through fiber density optimization. Testing was performed with four fiber bundle configurations ranging from 35,850 fibers to 41,180 fibers. The optimal configuration reduced the Gen4 SWME envelope volume by 15% from that of Gen3 while dramatically increasing the performance margin of the system. A rectangular block design was chosen over the Gen3 cylindrical design, for packaging configurations within the AEMU PLSS envelope. Several important innovations were made in the redesign of the backpressure valve which is used to control evaporation. A twin-port pivot concept was selected from among three low profile valve designs for superior robustness, control and packaging. The backpressure valve motor, the thermal control valve, delta pressure sensors and temperature sensors were incorporated into the manifold endcaps, also for packaging considerations. Flight-like materials including a titanium housing were used for all components. Performance testing of the Gen4 SWME is underway.

TFAWS2014-AT-09

Mini-Membrane Evaporator for Contingency Spacesuit Cooling

Janice V. Makinen, NASA JSC
Grant C. Bue, NASA JSC
Colin Campbell NASA JSC
Jesse Craft, Jacobs Engineering
William Lynch, Jacobs Engineering
Robert Wilkes, Jacobs Engineering
Matthew Vogel, Jacobs Engineering

Abstract
The next-generation Advanced Extravehicular Mobility Unit (AEMU) Portable Life Support System (PLSS) is integrating a number of new technologies to improve reliability and functionality. One of these improvements is the development of the Auxiliary Cooling Loop (ACL) for contingency crewmember cooling. The ACL is a completely redundant, independent cooling system that consists of a small evaporative cooler—the Mini Membrane Evaporator (Mini-ME), independent pump, independent feedwater assembly and independent Liquid Cooling Garment (LCG). The Mini-ME utilizes the same hollow fiber technology featured in the full-sized AEMU PLSS cooling device, the Spacesuit Water Membrane Evaporator (SWME), but Mini-ME occupies only 25% of the volume of SWME, thereby providing only the necessary crewmember cooling in a contingency situation. The ACL provides a number of benefits when compared with the current EMU PLSS contingency cooling technology, which relies upon a Secondary Oxygen Vessel; contingency crewmember cooling can be provided for a longer period of time, more contingency situations can be accounted for, no reliance on a Secondary Oxygen Vessel (SOV) for contingency cooling—thereby allowing a reduction in SOV size and

pressure, and the ACL can be recharged—allowing the AEMU PLSS to be reused, even after a contingency event. The first iteration of Mini-ME was developed and tested in-house. Mini-ME is currently packaged in AEMU PLSS 2.0, where it is being tested in environments and situations that are representative of potential future Extravehicular Activities (EVA's). The second iteration of Mini-ME, known as Mini-ME2, is currently being developed to offer more heat rejection capability. The development of this contingency evaporative cooling system will contribute to a more robust and comprehensive AEMU PLSS.

TFAWS2014-AT-10

Low Cost Radiator for Fission Power Thermal Control

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John R. Hartenstine, Advanced Cooling Technologies
Calin Tarau, Advanced Cooling Technologies
William G. Anderson, Advanced Cooling Technologies
Ted Stern, Vanguard Space Technologies
Nicholas Walmsley, Vanguard Space Technologies
Maxwell Briggs, NASA GRC

Abstract

NASA Glenn Research Center (GRC) is developing fission power system technology for future Lunar surface power applications. The systems are envisioned in the 10 to 100kW$_e$ range and have an anticipated design life of 8 to 15 years with no maintenance. NASA GRC is currently setting up a 55 kW$_e$ non-nuclear system ground test in thermal-vacuum to validate technologies required to transfer reactor heat, convert the heat into electricity, reject waste heat, process the electrical output, and demonstrate overall system performance. Reducing the radiator mass, size, and cost is essential to the success of the program. Figure 1 illustrates a conventional dual facesheet VCHP radiator, and a single direct-bond facesheet radiator that is currently being developed under an SBIR program with NASA GRC.

TFAWS2014-AT-11

SINDA/FLUINT Stratified Tank Modeling for Cryogenic Propellant Tanks

Barbara Sakowski, NASA GRC

Abstract

A general purpose SINDA/FLUINT (S/F) stratified tank model was created and used to simulate tank pressurization as well as axial jet mixing within the liquid of the tank. The stratified layers in the vapor and liquid regions of the tank are modeled using S/F lumps. The model was constructed to analyze a general purpose stratified tank that could incorporate the following additional features:

- Multiple or singular lumps in the liquid and vapor regions of the tank
- Real gases (also mixtures) and compressible liquids
- Venting, pressurizing, and draining
- Condensation and evaporation/boiling
- Wall heat transfer
- Elliptical, cylindrical, and spherical tank geometries

These features employ extensive user logic that could be tailored to a user's specific needs. Most of the code input for a specific case could be done through the Registers Data Block. Specific naming conventions for S/F nodes, lumps, and connectors are illustrated in great detail in an ASCII text format that explicitly guides the user in creating models. Results were compared to KSITE self-pressurization tests with and without axial jet mixing.

Paper Abstracts: Passive Thermal

Passive Thermal Paper Session I

TFAWS2014-PT-01

Adaptation of 25-Node Human Thermal Model for Use in Sierra Nevada Corporation's Dream Chaser® System-Level Thermal Desktop Model

R.S Mishkovish, ATA Engineering
J.V. Byerly, Sierra Nevada Corporation
S.W. Miller, Sierra Nevada Corporation

Abstract
Sierra Nevada Corporation ("SNC") is currently working with NASA's Commercial Crew Program to develop and configure the Dream Chaser spacecraft for transportation services to low-Earth orbit destinations, including the International Space Station (ISS). Part of this effort is a system-level thermal model of the vehicle to predict its thermal response during the various phases of flight, and to help with the design of active and passive thermal control systems. Since the Dream Chaser is capable of piloted or autonomous flight, the thermal response is important to the overall thermal design, especially in the crew configuration.

NASA and its contractors have developed various human thermal models since the 1960's. Two of note include the early 25-node human thermal model [STOLWIJK1971] and its successor, the 41-node METMAN model [BUE1989]. The model divides the human body into 6 or 10 compartments. Both models use 4 nodes to model the core, muscle, fat, and skin of each compartment. The final node is to model the blood flow. Heat losses due to convection, radiation, perspiration, and respiration are modeled. The major differences between these two models are that the 41-node model distinguishes between left and right arms and legs, and also has the ability to work with humans of various sizes. However, both of these models are executed in FORTRAN programs, and have not been adapted for public use in a system-level thermal model.

This paper describes how SNC and ATA Engineering, Inc. converted the 25-node thermal model for use in the Thermal Desktop system-level thermal model, and added features from the METMAN model to model humans of different size and anthropomorphic constituency. The models consist of a combination of SINDA nodes and conduction, along with control logic to compute the metabolic heat loads based on environmental conditions and human activity. The models can be connected to a cabin air node or to an LCG loop node. The model also allows for the ability to compute human CO2 and water vapor production for cabin air environment modeling.

TFAWS2014-PT-02

Precision Tracking Space System (PTSS) Infrared Sensor Thermal Testing and Model Correlation

Matt Felt, Space Dynamics Laboratory, Utah State University
Brian Thompson, Space Dynamics Laboratory, Utah State University
Lorin Zollinger, Space Dynamics Laboratory, Utah State University
Mike Marley, Applied Physics Laboratory/John Hopkins University
Ed Hawkins, Applied Physics Laboratory/John Hopkins University
Patrick Stadter, Applied Physics Laboratory/John Hopkins University

Abstract
The Precision Tracking Space System (PTSS) was a constellation of infrared (IR) sensors planned by the US Missile Defense Agency (MDA) to observe and track ballistic missile objects in flight. The PTSS program funded testing to characterize the parasitic heat loads expected on the actively-cooled multi-band IR sensor assembly, a subassembly within the optical telescope, thereby reducing uncertainty in the cooler heat lift requirements and system power budget. A detailed flight-like thermal analog of the sensor assembly, including designed conductances, surface treatments, and multi-layer insulation, was tested in a fixture that simulated its flight interfaces with a controllable interface temperature. A heat flow sensor, located at the flight cold-head attachment point, provided heat lift measurements. Testing was performed with various boundary conditions and a least squares fit was used to discriminate between the conduction and radiation parasitic heat load components. This knowledge was used to correlate a detailed thermal model built in Thermal Desktop that could then be used to accurately predict flight heat lift and perform system level design trades. This document presents a detailed description of the testing, test results, model correlation methodology and results, and lessons learned.

TFAWS2014-PT-03

Preliminary Development of a TSS and SINDA/FLUINT to ESARAD/ESATAN Thermal Model Converter

Kan Yang, NASA GSFC
Hume Peabody, NASA GSFC

Abstract
In collaborative spacecraft projects between NASA and ESA, cross-agency exchanges of thermal models are necessary to facilitate thermal design as well as generate temperature and heat predictions at the observatory level. The standard thermal software used within NASA for the Geometric Math Model (GMM) is typically the Thermal Synthesizer System (TSS) or Thermal Desktop, while SINDA/G or SINDA/FLUINT is used for the Thermal Math Model (TMM). However, the standard for the majority of ESA projects remains ESARAD for the GMM and ESATAN for the TMM. Although ESATAN was developed from a SINDA-like framework, several crucial differences in thermal model structure and GMM features make any effort to translate between the two model formats a painstaking task. A recent effort has been initiated by the

NASA Goddard Thermal Engineering Branch to develop a standardized converter between the TSS with SINDA/FLUINT and ESATAN/ESARAD formats. Developed in the VB.NET language, this converter tool provides a Graphical User Interface (GUI) to facilitate the conversion process among end users, and employs a framework of two top-level classes for importing, manipulating, and exporting data from GMMs and TMMs. The GMM class stores information regarding input and output files, units, emulation for unsupported surface types, and data structures for Entities, Variables, Optical Properties, and Thermophysical Properties. For surfaces that require emulation, the GMM converter also seeks to devolve more complex geometries into base primitive shapes such that they can be passed between programs. The TMM class stores information regarding nodes, conductors, arrays, and registers, and converts all data types supported by both programs. A preliminary effort has also been made to translate model logic between SINDA/FLUINT and ESATAN. It is hoped that development of this conversion tool will facilitate inter-agency collaborations for NASA and its ESA partners on current and future projects.

TFAWS2014-PT-04

Thermal Control Design for the Subarcsecond Telescope and Balloon Experiment (STABLE)

Hared Ochoa, NASA JPL
Robert Effinger, NASA JPL
Rachael Tompa, NASA JPL
Michael Porter NASA JPL

Abstract

The thermal modeling, design and analysis of the Subarcsecond Telescope and BaLloon Experiment (STABLE) payload is presented. STABLE is a high precision pointing demonstration project and is part of the BIT-STABLE mission (Balloon-borne Imaging Testbed). BIT-STABLE has three main contributors: the Jet Propulsion Laboratory, the University of Toronto, and the University of Durham (UK). The STABLE payload, whose main optical element is a 50 cm aperture telescope, will fly on a high altitude balloon inside the BIT gondola designed by the University of Toronto. Once at float, the STABLE payload will use a point source of visible light to demonstrate pointing precision within 0.1 arc seconds for at least 60 seconds. This paper will discuss the thermal design and analysis of the STABLE payload. The wide range in potential thermal environments and the thermal sensitivity of the off-the-shelf telescope impose a challenge to the thermal control system. The design calls for a thorough investigation and understanding of the flight environments, detailed modeling and analysis, and strategically chosen passive hardware to bias the payload cold and active hardware to heat the payload to the optimal temperature ranges. Along with a detailed discussion on the thermal design this paper will also review the expected thermal performance of the system and the uncertainties of the model and design. STABLE is a project under the JPL Phaeton program—a training program for early career hires.

TFAWS2014-PT-05

LUROVA – From Render Engine to Thermal Model

Ron Creel, NASA Veteran

Abstract

Render Engine created surface data provides high quality polygon faces and vertex information for potential use in constructing thermal radiation analytical models. The original Apollo LUnar ROVing Adventures (LUROVA) mission support thermal model, presented at TFAWS-2006, has been restored and upgraded using detailed render engine surface data. Polygon crunching and other developed surface data conversion and visualization software was used to reduce 800,000+ "faces" and 400,000+ "vertices" into a representative and manageable smaller surface model (~7800 surface nodes) to be run on the NASA Thermal Radiation Analysis System (TRASYS) computer program. The surface data conversion process is described, and the calculated surface radiation and heating environments for the enhanced thermal model are compared to previous mission support analysis results. Future plans for LUROVA thermal model and "Edutainment" game/simulation enhancements are also discussed.

TFAWS2014-PT-10

Thermal Modeling and Test Correlation for the High Fidelity Data Acquisition System

Chris Evans, MSFC

Abstract

This paper discusses the thermal modeling of the High Fidelity Data Acquisition System (HiDAQ) avionics box, including an assessment of copper versus aluminum heat spreaders and post-test model correlation. HiDAQ is a compact electronics "black box" designed for data recording in harsh acoustic and thermal environments, such as areas around a rocket motor. To provide thermal management and vibration protection, the box is filled and completely sealed with a thermally conductive epoxy. Embedded metal heat spreader plates are also utilized to channel the heat from the densely-packed electronics. Thermal models of the box and its internal boards/components were developed in Thermal Desktop to predict component temperatures and to assess the ability of the internal epoxy and heat spreader design to meet thermal requirements. The models were also used to perform simulations with alternative heat spreader material options in an effort to reduce weight and cost. Thermal test data was used to partially validate the models. This paper summarizes the thermal model, heat spreader material trade study, assessment of the effect of the epoxy fill in assisting thermal control, and the test correlation efforts.

Passive Thermal Paper Session II

TFAWS2014-PT-06

Thermal Interface Materials and Challenges Faced by Thermal Interface Material Suppliers

Jason Strader, Laird
Rich Hill, Laird

Abstract

Many electronic components generate excess heat requiring a variety of methods and cooling devices such as heat sinks, heat pipes, and even water cooling. In order to optimize the thermal contact between the electronic device and heat removal components, a thermal interface material is generally placed in-between in order to fill in the interstitial spaces between the non-flat non-planar surfaces. We will present the wide variety of thermal interface materials available, and discuss the various situations each are typically used in and why. Thermal interface suppliers encounter many challenges including customer interpretation of specifications, maintaining consistent performance for many years, and issues presented by raw material supplies. Methods to avoid and/or solve these issues will be introduced.

TFAWS2014-PT-07

LTCS (Laser Thermal Control System) Test Supporting the Improvement of DeCoM (Deepak Condenser Model)

Deepak Patel, GSFC

Abstract

On Dec. 2013 a Loop Heat Pipe (LHP) test was performed as part of the integral Laser Thermal Control System (LTCS). During the balance portion of this testing it was noticed that the LHP was not going to be able to maintain temperature on the operational thermal mass. The test was stopped. After multiple meetings with the LTCS designers, LHP experts (in house and external) it was concluded that gravity was preventing the control heaters to maintain control on the reservoir. A heater was installed onto the liquid return line as part of the fix. After implementing the fix on the liquid return line, the test on May 2014 proved that the system works in vertical orientation using the liquid line heater. Through this testing, the correlation of the Deepak Condenser Model (DeCoM) was possible. This paper describes that DeCoM predicts the vapor and liquid behavior through the condenser well within 3C of the test temperatures. There is still much to understand at the exact two-phase location where the vapor starts condensing and liquid bubbles start forming. Future studies will focus on how to improve the code to accurately identify the exact phase change location.

TFAWS2014-PT-08

Using SpaceClaim/TD Direct for Modeling Components With Complex Geometries for the Thermal Desktop-based Advanced Stirling Radioisotope Generator Model

William Fabanich, NASA GRC

Abstract

SpaceClaim/TD Direct has been used extensively in the development of the Advanced Stirling Radioisotope Generator (ASRG) thermal model. This paper outlines the workflow for that aspect of the task and includes proposed best practices and lessons learned. The ASRG thermal model was developed to predict component temperatures and power output and to provide insight into the prime contractor's thermal modeling efforts. The insulation blocks, heat collectors, and cold side adapter flanges (CSAFs) were modeled with this process.

The model was constructed using mostly TD finite difference surfaces/solids. However, some complex geometry could not be reproduced with TD primitives while maintaining the desired degree of geometric fidelity. Using SpaceClaim permitted the import of original CAD files and enabled the defeaturing/repair of those geometries. TD Direct (a SpaceClaim plug-in from C&R Tech) adds features that allowed the "mark-up" of that geometry.

These mark-ups control how finite element (FE) meshes were generated and allowed the "tagging" of features (e.g. solids, surfaces). These tags represent parameters that include: submodels, material properties, material orienters, optical properties, and radiation analysis groups. TD aliases were used for most tags to allow analysis to be performed with a variety of parameter values. "Domain-tags" were also attached to individual and groups of surfaces and solids to allow them to be used later within TD to populate objects like, for example, heaters and contactors. These tools allow the user to make changes to the geometry in SpaceClaim and then easily synchronize the mesh in TD without having to redefine these objects each time as one would if using TD Mesher.

The use of SpaceClaim/TD Direct has helped simplify the process for importing existing geometries and in the creation of high fidelity FE meshes to represent complex parts. It has also saved time and effort in the subsequent analysis.

TFAWS2014-PT-09

Cube Flux Method to Generate Spacecraft Thermal Environments

Siraj A Jalali, Oceaneering Space Systems

Abstract

Spacecrafts are exposed to various environments that are not present at the surface of the earth, like plasmas, neutral gases, x-rays, ultraviolet (UV) irradiation, high energy charged particles, meteoroids, and orbital debris. The interaction of these environments with spacecraft cause degradation of materials, contamination, spacecraft glow, charging, thermal changes, excitation, radiation damage, and induced background interference. The damaging effects of

natural space and atmospheric environments pose difficult challenges for spacecraft designers. ISS/Shuttle thermal model was used to develop a program to determine environment around an orbiting spacecraft. The method was applied to compare environments around the ISS/Shuttle in Earth and Mars orbits. The method was also applied on a Satellite in Lower Earth Orbit (LEO) and Geosynchronous Orbit (GEO) and results were compared.

To determine the thermal environments around the ISS/shuttle 1 cubic foot arithmetic cubes were placed 1 foot above the surfaces where thermal environments were needed. The ISS/Shuttle was placed in Earth and Mars orbits with required beta, attitudes, and altitude. The applicable solar, Albedo, and IR fluxes were applied on the model depending upon summer or winter solstice. Model was analyzed such that absorbed solar fluxes and surface temperatures of all cube surfaces were obtained. A routine (HTFLXCAL) was developed to calculate Infrared fluxes for all cube surfaces using cube absorbed solar fluxes and surface temperatures. The solar and infrared fluxes at a cube location were used to calculate orbital sink temperatures at that location. The sink temperatures at a cube location for tools, spacecraft surfaces, or space suit are extreme temperatures those components will be exposed to at that location.

The method presented here is efficient and simpler since the space vehicle model and flux generation routine (HTFLXCAL) are run from Thermal Desktop® in a single run, and Solar and IR fluxes for all cube locations are generated. The sink temperatures generation routine for required materials using Solar and IR fluxes is also part of the main routine.

TFAWS2014-PT-11

Passive Thermal Design approach for the Space Communications and Navigation (SCaN) experiment on the International Space Station (ISS)

John Siamidis, NASA GRC

Abstract
The SCaN payload provides an on-orbit, adaptable, SDR/STRS-based facility to conduct a suite of experiments to advance the Software Defined Radio (SDR) Space Telecommunications Radio Systems (STRS) Standards, reduce risk (TRL advancement) for candidate Constellation space flight hardware/software, and demonstrate space communication links critical to future NASA exploration missions.

The SCaN Project provides NASA, industry, other Government agencies, and academic partners the opportunity to develop and field communications, navigation, and networking technologies in the laboratory and space environment based on reconfigurable, software defined radio platforms and the STRS Architecture.

The SCaN payload is resident on the P3 Express Logistics Carrier (ELC) on the exterior truss of the International Space Station (ISS). The SCaN payload launched on the Japanese Aerospace Exploration Agency (JAXA) H-II Transfer Vehicle (HTV) and was installed on the International Space Station (ISS) P3 ELC located inboard RAM P3 site.

Paper Abstracts: Aerothermal

TFAWS2014-AE-01

A New High Temperature Thermopile Heat Flux Sensor at AEDC (ITAR)

Stuart Coulter, Aerospace Testing

Abstract

This abstract is unable to be released in this document due to ITAR restrictions. A copy of the abstract and paper submission will be available upon request to attendees meeting the ITAR requirements (U.S. Citizen or Permanent Resident). Please direct such requests to the paper session chairs.

TFAWS2014-AE-02

Space Shuttle Boundary Layer Transition Flight Experiment Ground Testing Overview

Karen Berger, NASA LaRC
Brian Anderson, NASA JSC
Charles Campbell, NASA JSC

Abstract

In support of the Boundary Layer Transition (BLT) Flight Experiment (FE) Project in which a manufactured protuberance tile was installed on the port wing of Space Shuttle Orbiter Discovery for STS-119, STS-128, STS-131 and STS-133 as well as Space Shuttle Endeavour for STS-134, a significant wind tunnel test campaign was completed. The primary goals of the test campaign were to provide ground test data to support the planning and safety certification efforts required to fly the flight experiment as well as validation for the collected flight data. These test included Arcjet testing of the tile protuberance, aerothermal testing to determine the boundary layer transition behavior and resultant surface heating and planar laser induced fluorescence (PLIF) testing in order to gain a better understanding of the flow field characteristics of the flight experiment. This paper provides an overview of the BLT FE Project ground testing. High-level overviews of the facilities, models, test techniques and data are presented, along with a summary of the insights gained from each test.

TFAWS2014-AE-03

Langley Aerothermodynamic Labs: Testing Capabilities

Kevin Hollingsworth, Jacobs Technology
Sheila Wright, Jacobs Technology
Karen Berger, NASA LaRC
Shann Rufer, NASA LaRC

Abstract

A description of the NASA Langley Research Center's (LaRC) Langley Aerothermodynamics Laboratory (LAL) will be presented in the paper, along with descriptions and details of the facility test techniques and recent upgrades. The LAL consists of three hypersonic blow-down wind tunnels with Mach numbers of 6 and 10 and Reynolds number ranges of 0.5 to 8 million per foot as well as a 60-ft Vacuum Sphere Test Chamber. All three wind tunnel facilities utilize dried, filtered and heated air as the test gas. LAL facilities are used to study and define the aerodynamic performance and aeroheating characteristics of flight vehicle concepts. Data collected in the facilities has been used for design and optimization, anchoring computations predictions, generation of aerodynamic databases, and design of Thermal Protection Systems (TPS). Over the years since initial construction, modifications and enhancements have been made to the facility hardware and instrumentation to increase efficiency, data quality, capabilities and reliability to better meet the programmatic requirements. Recent utilization information illustrates the need for the capabilities associated with these facilities. Test programs to utilize the facilities recently include the Space Shuttle Program, Crew Exploration Vehicle (CEV)/Orion, Hypersonic International Flight Research Experimentation (HIFiRE), Mars Science Laboratory (MSL), Hypersonic Inflatable Aerodynamic Decelerator System (HIADS) and X-51 among others and usage has been split between NASA, Department of Defense and private company programs. Plans for future improvements to the facility infrastructure and instrumentation will also be presented.

Paper Abstracts: Interdisciplinary

TFAWS2014-I-01

SRTMV-N2 Plume Impingement Test Panel Thermal Analysis

Vincent Cuda Jr., NASA LaRC
David Witte, NASA LaRC
Jason Mishtawy, NASA MSFC
Jeremy Pinier, NASA LaRC

Abstract
A heavily instrumented, 15-5 stainless steel test panel (30 inches wide by 36 inches in length by 1.0 inches in thickness), referred to as the Plume Impingement Test Panel was instrumented with over 200 thermal and pressure sensors and positioned 48 inches downstream of a 24-inch diameter solid rocket test motor to intersect with the expanding exhaust gas from the rocket nozzle. The panel was inclined six degrees into the exhaust resulting in the aft end penetrating further into the exhaust plume. The instrument suite employed a novel array of thermal sensors to provide three different approaches to determining the surface heat flux along the test panel. One direct heat flux sensor measurement technique was employed along with two indirect temperature measurement techniques to deduce the surface heat flux. The panel also included the installation of two thermal protection system (TPS) samples. One test coupon of VAMAC and one of P-50 cork were installed near the aft end of the test panel above centerline to expose these two TPS samples to the highest expected heating loads.

The data record from the thermal instrumentation provided a detailed description of the exhaust plume environment. The outer exhaust plume region had radiant heating profiles larger than expected. The total surface heating profiles downstream of the plume impingement point on the test panel were consistent with convection dominated heating. No exhaust plume core heating was evident on the test panel. Comparison of the three different methods for determining total surface heat transfer rate showed fairly good agreement during the initial portion of the test. The data from this test can be used to validate CFD predictions of the aerothermal loads from plume impingement.

TFAWS2014-I-02

Flow Characteristics of a Strut Injector for Scramjets: Numerical and Experimental Results

Cody Ground, Aerodynamics Research Center, University of Texas at Arlington
Fabrizio Vergine, Aerodynamics Research Center, University of Texas at Arlington
Luca Maddalena, Aerodynamics Research Center, University of Texas at Arlington
Valerio Viti, ANSYS, Inc.

Abstract
A peculiar dynamical interaction of two supersonic counter-rotating vortex pairs (CVPs) has been generated by a pair of overlapping expansion ramps mounted on a strut injector in a Mach 2.5 flow. Similar CVP configurations generated by overlapping ramps on the same modular strut injector have previously been studied by the authors and experimentally corroborated the predictions based on the in-house developed reduced order model, VorTx. Two co-rotating vortices at the center of the generated structure have either merged or begun to orbit each other. However, for the case discussed in this work, experiments have revealed an additional structure; in fact, instead of the expected four streamwise vortices in the flowfield consisting of two inner co-rotating vortices and two oppositely rotating external vortices, the formation of a fifth structure, a central vorticity patch, was detected. The manuscript presents a detailed experimental characterization of the flow of interest via the use of stereoscopic particle image velocimetry and a parallel computational effort based on the solution of the Reynolds Averaged Navier-Stokes equations with the ANSYS Fluent CFD Package. The results of the CFD simulations highlight the near injector flowfield, which is unable to be characterized experimentally, in order to focus upon the mechanism that result in the formation and the effects of the central vorticity patch.

TFAWS2014-I-04

Thermal Acoustic Oscillation: Causes, Detection, Analysis and Prevention

Robert J. Christie, NASA GRC
Jason W. Hartwig, NASA GRC

Abstract
Thermal Acoustic Oscillations (TAO) can occur in cryogenic systems and produce significant sources of heat. This source of heat can increase the boil-off rate of cryogenic propellants in spacecraft storage tanks and reduce mission life. This paper discusses the causes of TAO, how it can be detected, what analyses can be done and how to prevent it from occurring. The paper provides practical insight into what can aggravate instability, practical methods for mitigation and when TAO does not occur. A real life example of a cryogenic system with an unexpected heat source is discussed, along with how TAO was confirmed and eliminated.

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