PASSIVE THERMAL SESSION TOPICS

Passive Thermal Paper Session I (Wednesday 7:30AM to 11:30AM)

Time	ID	Title	Author(s)	Affiliation	Email
7:30AM	TFAWS2012-PT-01	Thermal Optimization and Assessment of a Long Duration Cryogenic Propellant Depot	Ryan Honour Robert Kwas Gary O'Neil Bernard Kutter	NASA KSC, United Launch Alliance	Ryan.honour@nasa.gov
8:00AM	TFAWS2012-PT-02	Development of the GPM Observatory Thermal Vacuum Test Model	Kan Yang Hume Peabody	NASA GSFC	Kan.yang@nasa.gov
8:30AM	TFAWS2012-PT-03	Return to Mercury: An Overview of the MESSENGER Spacecraft Thermal Control System Design and Up-to-Date On-Orbit Flight Performance	Carl J. Ercol	The Johns Hopkins University	Carl.ercol@jhuapl.edu
9:00AM	TFAWS2012-PT-04	Method for Importing Multiple Nastran Composite Layups into Thermal Desktop Accounting for Through-Panel Radiation	Matt Garrett Victoria Harris Alanna Koser	ATA Engineering, Inc.	Mgarrett@ata-e.com
10:00AM	TFAWS2012-PT-05	Thermal and Fluid Modeling of the Cryogenic Orbital Testbed (CRYOTE) Ground Test Article (GTA)	David Piryk Paul Schallhorn Laurie Walls Bernard Kutter Noah Rhys Mark Wollen	NASA KSC, United Launch Alliance, Yetispace, Inc., Innovative Engineering Solutions	David.a.pink@nasa.gov
10:30AM	TFAWS2012-PT-06	Modeling of Heat Transfer and Ablation of Refractory Material due to Rocket Plume Impingement	Michael F. Harris Dr. Bruce T. Vu	QinetiQ, NASA KSC	Michael.f.harris@nasa.gov
11:00AM	TFAWS2012-PT-07	Cube Flux Method to Generate Spacecraft Thermal Environments	Siraj A. Jalali	Oceaneering Space Systems	Si.al.ali@oceaneering.com

Passive Thermal Paper Session II (Thursday 1:00PM to 3:00PM)

Time	ID	Title	Author(s)	Affiliation	Email
1:00PM	TFAWS2012-PT-08	A Design Overview of The Thermal Control System For The Earth Orbiting SMAP Mission	Nickolas Emis Eug Kwack Rebecca Mikhaylov Danford Lau Jennifer Miller Gordy Cucullu	JPL	Nickolas.Emis@jpl.nasa.gov
1:30PM	TFAWS2012-PT-09	Thermal Analysis Using Assembly FEMs in Teamcenter, NX and Space Systems Thermal	Robert Krylo	JPL	Robert.J.Krylo@jpl.nasa.gov
2:00PM	TFAWS2012-PT-10	Review and Assessment of JPL's Thermal Margins (AIAA San Diego, CA, 42^{nd} ICES Conference)	George Siebes Arturo Avila, Michael Blakely, Christine Farguson, A. Hoffman1, Cynthia Kingery, K. Man, Jeffrey Nunes, Mark White	JPL	Georg.Siebes@jpl.nasa.gov
2:30PM	TFAWS2012-PT-11	Conductive White Thermal Control Polyimide Films with Atomic Oxygen Durability	Garrett D. Poe	NeXolve	Garrett.poe@nexolve.com

TFAWS2012-PT-01

THERMAL OPTIMIZATION AND ASSESSMENT OF A LONG DURATION CRYOGENIC PROPELLANT DEPOT

Ryan Honour, NASA Kennedy Space Center
Robert Kwas, NASA Kennedy Space Center
Gary O'Neil, NASA Kennedy Space Center
Bernard Kutter, United Launch Alliance

ABSTRACT

A Cryogenic Propellant Depot (CPD) operating in Low Earth Orbit (LEO) could provide many near term benefits to NASA space exploration efforts. These benefits include elongation/extension of spacecraft missions and reduction of launch vehicle up-mass requirements. Some of the challenges include controlling cryogenic propellant evaporation and managing the high costs and long schedules associated with new spacecraft hardware development. This paper describes a conceptual CPD design that is thermally optimized to achieve extremely low propellant boil-off rates. The CPD design is based on existing launch vehicle architecture and its thermal optimization is achieved using current passive thermal control technology. Results from an integrated thermal model are presented showing that this conceptual CPD design can achieve propellant boil-off rates well under 0.05% per day, even when subjected to the LEO thermal environment.

TFAWS2012-PT-02

DEVELOPMENT OF THE GPM OBSERVATORY THERMAL VACUUM TEST MODEL

Kan Yang, NASA Goddard Space Flight Center
Hume Peabody, NASA Goddard Space Flight Center

ABSTRACT

A software-based thermal modeling process was documented for generating the thermal panel settings necessary to simulate worst-case on-orbit flight environments in an observatory-level thermal vacuum test setup. The method for creating such a thermal model involved four major steps: (1) determining the major thermal zones for test as indicated by the major dissipating components on the spacecraft, then mapping the major heat flows between these components; (2) finding the flight equivalent sink temperatures for these test thermal zones; (3) determining the thermal test ground support equipment (GSE) design and initial thermal panel settings based on the equivalent sink temperatures; and (4) adjusting the panel settings in the test model to match heat flows and temperatures with the flight model. The observatory test thermal model developed from this process allows quick predictions of the performance of the thermal vacuum test design.

In this work, the method described above was applied to the Global Precipitation Measurement (GPM) core observatory spacecraft, a joint project between NASA and the Japanese Aerospace Exploration Agency (JAXA) which is currently being integrated at NASA Goddard Space Flight Center. From preliminary results, the thermal test model generated from this process shows that the heat flows and temperatures match fairly well with the flight thermal model, indicating that the test model can simulate fairly accurately the conditions on-orbit. However, further analysis is needed to determine the best test configuration possible to validate the GPM thermal design before the start of environmental testing later this year. Also, while this analysis method has been applied solely to GPM, it should be emphasized that the same process can be applied to any mission to develop an effective test setup and panel settings which accurately simulate on-orbit thermal environments.

TFAWS2012-PT-03

RETURN TO MERCURY: AN OVERVIEW OF THE MESSENGER SPACECRAFT THERMAL CONTROL SYSTEM DESIGN AND UP-TO-DATE ON-ORBIT FLIGHT PERFORMANCE

Carl J. Ercol, The Johns Hopkins University Applied Physics Laboratory

ABSTRACT

AT 01:00 UTC on March 18, 2011, MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) became the first spacecraft to achieve orbit around the planet Mercury. Designed and built by The Johns Hopkins University Applied Physics Laboratory in conjunction with the Carnegie Institution of Washington, MESSENGER was launched on August 3, 2004 and has recently completed its primary mission of a 1-year orbital phase to study Mercury. Currently, MESSENGER has successfully completed the yearlong primary mission and is in the initial phase of a yearlong extended mission to gather more science with a shortened orbit period. Prior to orbit injection at Mercury the spacecraft completed a 7-year cruise phase that has included a flyby of the Earth (August 2005), two flybys of Venus (October 2006 and June 2007), and three flybys of Mercury (January and October, 2008 and October 2009). The January 2008 Mercury flyby marked the first spacecraft visit since Mariner 10 (1975) and made MESSENGER the first spacecraft to encounter Mercury when near the planet's perihelion. This paper will provide an overview of the thermal design challenges for both the cruise and orbital phases and the flight temperature and power data that verify the performance of the thermal control subsystem over the mission to date.

TFAWS2012-PT-04

METHOD FOR IMPORTING MULTIPLE NASTRAN COMPOSITE LAYUPS INTO THERMAL DESKTOP ACCOUNTING FOR THROUGH-PANEL RADIATION

Matt Garrett, ATA Engineering, Inc.
Victoria Harris, ATA Engineering, Inc.
Alanna Koser, ATA Engineering, Inc.

ABSTRACT

Increasingly, aerospace structures are designed and fabricated using composite materials. For the thermal analyst, this means that models often must incorporate materials with orthotropic, temperature-dependent properties on complex geometries. It is especially important that thermal models account for the typically low transverse conductivity through composite panels, since this can lead to significant temperature differences across panels. Complicating the problem, aerospace structures frequently consist of hundreds of distinct composite layups applied to arbitrary geometry. Structural analysis tools such as Nastran offer analysts convenient methods for defining composite layups and applying them to the analysis mesh (e.g., with PCOMP cards), but commercial thermal analysis packages currently do not feature such conveniences. ATA Engineering, Inc. (ATA) has developed a method to automatically import an arbitrary number of composite layups defined in Nastran into a Thermal Desktop model and apply them to the analysis mesh. This method was used successfully during system-level analysis of a crewed spacecraft that featured over 200 distinct composite layups, each with several dozen material layers. For the thermal model, each of the layups was automatically translated into an effective orthotropic material and applied at the correct orientation to solid elements representing the structure. The present paper discusses the method with a comparison to results from detailed panel models (which would be unsuitable for system-level analysis), and introduces a refinement that will account for radiation across honeycomb layers as a parallel heat transfer path incorporated into the effective temperature-dependent orthotropic properties. The method shows excellent steady-state and transient agreement with the detailed models at a fraction of the computational cost, making it ideal for creating system-level models of aerospace structures featuring composite panels.

TFAWS2012-PT-05

THERMAL AND FLUID MODELING OF THE CRYOGENIC ORBITAL TESTBED (CRYOTE) GROUND TEST ARTICLE (GTA)

David Piryk, NASA Kennedy Space Center
Paul Schallhorn, NASA Kennedy Space Center
Laurie Walls, NASA Kennedy Space Center
Bernard Kutter, United Launch Alliance
Noah Rhys, Yetispace, Inc. (MSFC)
Mark Wollen, Innovative Engineering Solutions

ABSTRACT

The CRYOTE concept is for a low cost orbital testbed designed to perform cryogenic fluid management experiments in a micro-gravity environment. In lieu of this concept, a ground test article was developed to characterize heat loads in a 1G environment. The purpose of this study is to anchor thermal and fluid system models to CRYOTE ground test data. The CRYOTE ground test article was jointly developed by Innovative Engineering Solutions, United Launch Alliance and NASA KSC. The test article is constructed out of a titanium alloy tank, composite skirt, an external secondary payload adapter ring, thermal vent system, multi layer insulation and various data acquisition instrumentation. In efforts to understand heat loads throughout this system, the GTA is subjected to a series of tests in a vacuum chamber at Marshall Space Flight Center using nitrogen. By anchoring analytical models against test data, higher fidelity thermal environment predictions can be made for future flight articles demonstrating critical cryogenic fluid management technologies such as system chilldown, transfer, pressure control and long term storage. Significant factors that influence heat loads include radiative environments, multi-layer insulation performance, tank fill levels and pressures and even contact conductance coefficients. This research demonstrates how analytical thermal/fluid networks are established and includes supporting rationale for specific thermal responses seen during testing.

TFAWS2012-PT-06

MODELING OF HEAT TRANSFER AND EROSION OF REFRACTORY MATERIAL DUE TO ROCKET PLUME IMPINGEMENT

Mr. Michael F. Harris, QinetiQ
Dr. Bruce T. Vu, NASA Kennedy Space Center

ABSTRACT

CR Tech's Thermal Desktop-SINDA/FLUINT software was used in the thermal analysis of a flame deflector design for Launch Complex 39B at Kennedy Space Center, Florida. The analysis of the flame deflector takes into account heat transfer due to plume impingement from expected vehicles. The heat flux from the plume was computed using computational fluid dynamics provided by Ames Research Center in Moffet Field, California. The results from the CFD solutions were mapped onto a 3-D Thermal Desktop model of the flame deflector using the boundary condition mapping capabilities in Thermal Desktop. The ablation subroutine in SINDA/FLUINT was then used to model the erosion of the refractory material, such as Fondu Fyre.

TFAWS2012-PT-07

CUBE FLUX METHOD TO GENERATE SPACECRAFT THERMAL ENVIRONMENTS

SIRAJ A. JALALI, PH.D., P.E., 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 cube flux method has been developed previously also, but 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.

TFAWS2012-PT-08

A DESIGN OVERVIEW OF THE THERMAL CONTROL SYSTEM FOR THE EARTH ORBITING SMAP MISSION

Nick Emis, Jet Propulsion Laboratory, California Institute of Technology
Eug Kwack, Jet Propulsion Laboratory, California Institute of Technology
Rebecca Mikhaylov, Jet Propulsion Laboratory, California Institute of Technology
Danford Lau, Jet Propulsion Laboratory, California Institute of Technology
Jennifer Miller, Jet Propulsion Laboratory, California Institute of Technology
Gordy Cucullu, Jet Propulsion Laboratory, California Institute of Technology

ABSTRACT

The SMAP (Soil Moisture Active Passive) mission will provide high resolution mapping of the Earth's soil moisture and its freeze/thaw states with a low Earth orbiting spacecraft that is scheduled for launch in October 2014. This science data is used to extend the weather and climate forecasting skill, study the water/carbon/energy cycles, and improve flood and drought prediction capabilities. Global coverage is provided in 2-3 days from the 685 km polar orbit. The SMAP observatory is divided into a spun instrument portion (provided by JPL, GSFC, Boeing, Astro) and the spacecraft portion (provided by JPL). The science complement includes a radiometer and synthetic aperture radar instrument, both of which operate in the L-band and share a 6m diameter rotating mesh reflector antenna. The spun portion consists of the radiometer, spin assembly, control electronics, and the boom/reflector assembly, all rotating at ~14 rpm. The de-spun spacecraft is comprised of the propulsion, power, telecom, and radar subsystems. SMAP uses a primarily passive thermal design with active heater control to provide a simple and robust thermal solution with minimal risk. An overview of the thermal design strategies used for the SMAP mission, with some discussion on relevant analyses already performed, are described in this presentation.

TFAWS2012-PT-09

THERMAL ANALYSIS USING ASSEMBLY FEMS IN TEAMCENTER, NX AND SPACE SYSTEMS THERMAL

Robert Krylo, Jet Propulsion Laboratory, California Institute of Technology

ABSTRACT

The ability to create a thermal model directly onto an assembly of CAD parts in a controlled database has great potential for the thermal design a spacecraft. A suite of software tools that make this possible is Teamcenter, for managing the database, NX, for creating CAD geometry, and Space Systems Thermal for building and solving the thermal model. Creating the thermal model directly onto the CAD geometry links the thermal model to the parts in the database. Thermal and mechanical engineers then work concurrently within the same database. An Earth-orbiting spacecraft has been analyzed with this approach. This presentation covers the creation and solution of an assembly thermal model in a controlled database environment starting from a part assembly in NX.

TFAWS2012-PT-10

REVIEW AND ASSESSMENT OF JPL'S THERMAL MARGINS

George Siebes, Jet Propulsion Laboratory, California Institute of Technology
Arturo Avila, Jet Propulsion Laboratory, California Institute of Technology
Michael Blakely, Jet Propulsion Laboratory, California Institute of Technology
Christine Farguson, Jet Propulsion Laboratory, California Institute of Technology
A. Hoffman1, Jet Propulsion Laboratory, California Institute of Technology
Cynthia Kingery, Jet Propulsion Laboratory, California Institute of Technology
K. Man, Jet Propulsion Laboratory, California Institute of Technology
Jeffrey Nunes, Jet Propulsion Laboratory, California Institute of Technology
Mark White, Jet Propulsion Laboratory, California Institute of Technology
1retired

ABSTRACT

JPL has captured its experience from over four decades of robotic space exploration into a set of design rules. These rules have gradually changed into explicit requirements and are now formally implemented and verified. Over an extended period of time, the initial understanding of intent and rationale for these rules has faded and rules are now frequently applied without further consideration. In the meantime, mission classes and their associated risk postures have evolved, coupled with resource constraints and growing design diversity, bringing into question the current "one size fits all" thermal margin approach.
JPL's Office of Chief Engineer conducted a review of waivers, a formally approved deviation from required practices, associated with thermal margins and found an increasing number of waivers. These waivers apparently had no adverse impact on mission success. This prompted the formation of a multi-disciplinary team to assess the possibility of reducing thermal margins on the hot side with the goal of reducing the resources spent on processing waivers. The team quickly realized that the apparent lack of correlation between increased waivers and mission success does not provide a sufficient basis for conclusions regarding thermal margin. Instead, an in-depth assessment of the rationale for thermal reliability, qualification and other margins was necessary. Consequently, a systematic review of the heat flow path from an electronic junction to the eventual heat rejection to space was conducted. This resulted in a renewed understanding of JPL rules, which in turn enables better decision making.

TFAWS2012-PT-11

CONDUCTIVE WHITE THERMAL CONTROL POLYIMIDE FILMS WITH ATOMIC OXYGEN DURABILITY

Garrett D. Poe, Ph.D., NeXolve Corporation

ABSTRACT

Polyimides are attractive materials for passive thermal control due to their low mass, solar radiation resistance, and cryogenic flexibility. However, traditional polyimides are highly colored and as such are highly absorptive, intrinsically insulative, and have little or no intrinsic durability to atomic oxygen (AO). These inherent property shortfalls are usually overcome with the use of fillers and coatings. For example, the orange color can be overcoated with vapor deposited aluminum (VDA) or other metals to reduce the amount of heat absorbed; conductive carbon black is additives can be incorporated into the bulk of the polyimide used to render the material electrostatically dissipative; and the film can be protected from atomic oxygen with coatings. However, these approaches have associated shortfalls which present additional engineering challenges. For example, VDA has a low emissivity; conductive carbon black raises the thermal absorptivity; and coatings, when cracked or scratched, are no longer effective at protecting from AO. In response to these inherent limitations of existing thermal control materials, NeXolve has sought to overcome these challenges with Thermalbright and CORINbright thermal control polyimides, which are conductive white polyimides that are intrinsically AO durable and available in roll form. Thermal and mechanical properties will be presented, as well as MISSE flight data.