Passive Thermal Paper Session

Passive Thermal Paper Session #1 (Tuesday 1:00 PM to 3:00 PM)

ID	Title	Author(s)	Affiliation	Email
TFAWS-PT-001	Thermal Performance of a Cryogenic Fluid Management CubeSat Mission	J. J. Berg	NASA KSC	Jared.j.berg@nasa.gov
TFAWS-PT-002	Thermal/Optical Analysis of Cube Corner Retroreflectors for the Lunar Environment	Giovanni O. Delle Monache	INFN-LNF Frasati Italy/ University of Maryland	Giovanni.DelleMonache@lnf.infn.it
TFAWS-PT-003	Thermal Modeling and Analysis of the Hurricane Imaging Radiometer (HIRad)	Stephanie Mauro	NASA MSFC	Stephanie.L.Mauro@nasa.gov
TFAWS-PT-004	Modeling of Cryogenic Multilayer Insulation from Launch through Achieving Steady State	Wesley Johnson	NASA KSC	wesley.l.johnson@nasa.gov

Passive Thermal Paper Session #2 (Thursday 9:00 AM to 11:30 PM)

TFAWS-PT-005	Conjugate Fluid Flow/Solid Heat Transfer Simulations of the Flame Deflector Thermal Environment	Emre Sozer	NASA ARC	Emre.sozer@nasa.gov
TFAWS-PT-006	Cryogenic Liquid Level Sensing Using FOSS Technology	W. Lance Richards	NASA DFRC	Lance.richards-1@nasa.gov
TFAWS-PT-007	NASA LSP Vapor Migration Test Equipment Design	Tony Cook	UCF	cook_anthony@knights.ucf.edu
TFAWS-PT-008	NASA ISS Passive Thermal Control System Thermal Model Checkout	Laurie Carrillo	NASA JSC	Laurie.y.carrillo@nasa.gov
TFAWS-PT-009	Thermal Analysis of the Parachute System for the Low Density Supersonic Decelerator Project	Sandria Gray	NASA JPL	Sandria.L.Gray@jpl.nasa.gov

TFAWS-PT-001

Thermal Performance of a Cryogenic Fluid Management CubeSat Mission

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P. T. Putman and M. S. Haberbusch, Sierra Lobo, Inc., OH

ABSTRACT

Development for an in-space demonstration of a CubeSat as a Cryogenic Fluid Management test bed is currently underway. The favorable economics of CubeSats, successfully leveraged in the past by science payloads, are appealing for technology development activity. The manifesting of CubeSat payloads has increased substantially in recent years and is posed to continue climbing as the availability of commercial launch rideshare opportunities grows. While their size limits testing to smaller scales, many of the regimes relevant to CFM can still be achieved. The first demo flight of this concept, CryoCube®-1, will focus on oxygen liquefaction and low-gravity level sensing using Reduced Gravity CryoTracker®. An extensive thermal modeling effort has been underway to both demonstrate concept feasibility and drive the prototype design. The satellite will utilize both a sun- and earth-shield to passively cool its experimental tank below 115 K. An on-board gas generator will create high pressure gaseous oxygen, which will be throttled into a bottle in the experimental node and condense. The resulting liquid will be used to perform various experiments related to level sensing. Modeling efforts have focused on coupling the spacecraft thermal performance, gas generator system, and condensation in the experimental node to determine liquefaction rates and overall test bed performance. Parametric analyses for both optimal and suboptimal conditions have been considered and are presented herein.

TFAWS-PT-002

Thermal/Optical Analysis of Cube Corner Retroreflectors for the Lunar Environment

Giovanni Delle Monache and Simone Dell’ Agnello INFN-LNF Frasati, Italy
Douglas Currie and Bradfor Bher, University of Maryland, College Park, MD

ABSTRACT

Over the past 40 years, the Lunar Laser Ranging Program (LLRP) to the Apollo Cube Corner (CCR) Retroreflector Arrays (ALLRRA) has supplied almost all of the significant tests of General Relativity. This is the only Apollo experiment that is still in operation. Initially the ALLRRAs contributed a negligible fraction of the ranging error budget. Over the decades, the ranging capabilities of the ground stations have improved by more than two orders of magnitude. Now, because of the lunar librations, the existing Apollo retroreflector arrays contribute a significant fraction of the limiting errors in the range measurements. The University of Maryland, as the Principal Investigator for the original Apollo arrays, is now proposing a new approach to the Lunar Laser Array technology. The investigation of this new technology, with Professor Currie as Principal Investigator, is currently being supported by two NASA programs, two INFN experiments led by INFN-LNF Italy and, in minor part, by the Italian Space Agency. Thus after the proposed installation during the next lunar landing, the new arrays will support ranging observations that are a factor 100 more accurate than the current ALLRRAs. One of the most critical challenges is the issue of heat flows or thermal gradients inside the CCR. Since the index of refraction of the fused silica depends upon temperature, thermal gradients in the CCR will cause the index of refraction to vary within the CCR and thus it will not act as a diffraction-limited mirror. For this reason, we need to understand in detail the magnitude of the gradients caused by the various effects, and then adjust the design to control these gradients and finally evaluate the performance with the control procedures in place. We first need to determine the heat deposition. This is accomplished using dedicated programs developed in parallel at Frascati and at the University of Maryland. To perform these simulations, we use Thermal Desktop®. This analysis yields a three dimensional matrix describing the temperature distribution in the CCR for a given configuration and set of parameters.

A program developed at the University of Maryland using IDL of RSI Inc. converts the three dimensional temperature matrixes into a two-dimensional phase front, which captures the error induced by the temperature gradients. Results of an integrated model, which contains the passive thermal controlled experimental package, the model for the behavior of the regolith and the coupling of these effects are presented. The model has been parameterized to agree with the Heat Flow Experiment (HFE) deployed during the Apollo 16 mission by means of a Thermal Desktop® model of the Regolith down to 3 m depth developed by correlation to Apollo data and related articles. In addition this Regolith model is used to investigate current optical performance of Apollo 11 ALLRRA during eclipse, to evaluate degradation by possible lunar dust deposition. Preliminary results on Apollo 11 “dusted” ALLRRA model will be presented as well as preliminary thermo- optical test of the Moonlight package will be presented.

TFAWS-PT-003

Thermal Modeling and Analysis of the Hurricane Imaging Radiometer (HIRad)

Stephanie Mauro, NASA Marshall Space Flight Center, Huntsville, AL

ABSTRACT

The Hurricane Imaging Radiometer (HIRad) is a payload carried by an unmanned aerial vehicle (UAV) at altitudes up to 60,000 ft with the purpose of measuring ocean surface wind speeds and near ocean surface rain rates in hurricanes. The payload includes several components that must maintain steady temperatures throughout the flight. Minimizing the temperature drift of these components allows for accurate data collection and conclusions to be drawn concerning the behavior of hurricanes. HIRad has flown on several different UAVs over the past two years during the fall hurricane season. Based on the data from the 2011 flight, a Thermal Desktop model was created to simulate the payload and reproduce the temperatures. Using this model, recommendations were made to reduce the temperature drift through the use of heaters controlled by resistance temperature detector (RTD) sensors. The suggestions made were implemented for the 2012 hurricane season and further data was collected. The implementation of the heaters reduced the temperature drift for a portion of the flight, but after a period of time, the temperatures rose. With this new flight data, the thermal model was updated and correlated. Detailed analysis was conducted to determine a more effective way to reduce the temperature drift. The final recommendations made were to adjust the set temperatures of the heaters for 2013 flights and implement hardware changes for flights beyond 2013.

TFAWS-PT-004

Modeling of Cryogenic Multilayer Insulation from Launch through Achieving Steady State

Wesley Johnson, NASA Kennedy Space Center, FL

ABSTRACT

Cryogenic multilayer insulation has been studied extensively over the past sixty years, however, a large majority of that work has focused on the steady state parameters. There have been few efforts made to model the dynamic transients associated with rapid depressurization of the multilayer insulation during the first few minutes to days of flight. One of the main limitations in performing the testing is the required pump capacity to keep up with a launch vehicle beyond the first minute of flight.

For small cryogenic dewars (up to a few cubic meters) flown on science missions, the mass penalty associated with a vacuum jacket is not severe. However, for large upper stages and propulsion modules, this mass penalty has been shown to be unacceptable. The lack of the vacuum jacket requires the multilayer insulation to start out at atmospheric pressure or slightly above inside the fairing of the launch vehicle. As the payload fairing depressurizes, so does the MLI surrounding the tank until it eventually equilibrates sometime after launch. This initial steady state at atmospheric pressure causes the performance of the MLI to have roughly three orders of magnitude worse performance that steady state on orbit. During the depressurization transient, the performance begins to improve slowly, but takes time for the thin spaces between reflector layers to pump out. In order to get a better understanding of the physical phenomena that control the depressurization of the MLI, a detailed thermal model has been developed. This model uses a three node lumped parameter (liquid, vapor, and interface) as described by Moder (ref) contained within a volume defined by the geometry of the tank (both spherical and cylindrical with elliptical dome heads are supported). The MLI models include curve fits of historical test data that are allowed to vary in thickness, spacing, and depressurization rate. The tank wall and any insulation required during the ambient pressure portion for safety is also included both from a thermal mass and conductive heat load consideration. Additional modules have been constructed to look at layer by layer thermal changes in temperature and pressure, however, the run time incurred by invoking these models speaks strongly against their use and there is no method of verifying layer by layer pressures.

The model was run in conjunction with the Methane Lunar Surface Thermal Control testing performed at Glenn Research Center. The model was verified to the boil-off heat load as a function of time. This verification suggests that the model contains all portions of the physical phenomena that are of first order importance.

TFAWS-PT-005

Conjugate Fluid Flow/ Solid Heat Transfer Simulations of the Flame Deflector Thermal Environment

Emre Sozer, Christoph Brehm, and Shayan Moini-Yekta, Science & Technology Corp, Moffett Field, CA
Michael Barad, Jeff Housman, and Cetin Kiris, NASA Ames Research Center, Moffett Field, CA
Bruce Vu, NASA Kennedy Space Center, FL

ABSTRACT

Re-design of the Main Flame Deflector (MFD) for the 21st Century Launch Complex involves an objective of versatility so that it can accommodate launches of Space Launch System (SLS) vehicle as well as commercial vehicles such as Delta IV, Falcon Heavy and Liberty. In a rapidly evolving design environment, Computational Fluid Dynamics (CFD) proved to be an indispensable tool to guide the design process by quickly determining compatibility of a given MFD concept with the launches of aforementioned vehicles as well as providing essential insight to drive the next design iteration.

In traditional CFD simulations, one is presented with a choice of using either isothermal (or an imposed temperature distribution, if known) or adiabatic wall boundary conditions. In the case of the MFD, these approaches will yield overly conservative surface heat flux (if a cold wall is assumed) or temperature predictions, respectively. In both cases, the full picture of surface protective material performance remains elusive. Often, a separate post-processing tool is used for an estimate of boundary layer behavior for varying surface temperatures and corresponding convective heating and solid thermal response. These tools are expected to perform reasonably well for clearly defined, attached boundary layer flows where the underlying empirical correlations are deemed valid. However, they are not applicable at stagnation regions (such as impingement points) or separated regions.

In this work, time-accurate CFD simulations of the plume development and impingement are closely coupled with a 1-dimensional heat conduction simulation through the surface solid material. Realistic predictions of time-dependent surface heat flux and temperature distributions are directly obtained without the need for additional approximate tools.

TFAWS-PT-006

Cryogenic Liquid Level Sensing using FOSS Technology

W. Lance Richards, Allen R. Parker, Anthony Piazza, Patrick Hon Man Chan, NASA Dryden Flight Research Center, CA

ABSTRACT

In applications where cryogenic fluids are used, a method of discerning liquid level is important. In aerospace technology, there is a wide application potential for fiber optic sensing systems (FOSSs) to be used. Bragg-grated optical fibers are sensitive to both strain and temperature; however, using temperature to discern liquid levels has been fraught with challenges. The Cryo-FOSS was developed by NASA Dryden Flight Research Center to discern liquid levels with one compact, lightweight system.

Testing was conducted to first determine whether a FOSS device could accurately discern liquid levels in a cryogenic environment. When the results were promising, more specific testing was undertaken to qualitatively validate the Cryo-FOSS.

The Cryo-FOSS sensor is able to discern the liquid hydrogen (LH2) level in a dewar application to within 0.25 inch in all the tested fill levels. Agreement between the Cryo-FOSS and the validation system is excellent and proves the concept for a lightweight, accurate, spatially precise, and practical solution to a challenging problem for ground and in-flight cryogenic fluid management of future launch applications.

TFAWS-PT-007

NASA LSP Vapor Migration Test Equipment Design

Anthony Cook, William Boggs, Robert Gore, Kyle Harris, Michael Jasiukowicz, and Marcel Ilie, Mechanical and Aerospace Engineering Dept., University of Central Florida, Orlando, FL

ABSTRACT

The effects of launch conditions on the evolved expendable launch vehicle (EELV) payloads in the event of environmental control system (ECS) failure have led to the implementation of analytical models predicting the transient vapor migration from an ambient environment into the payload volume of the launch vehicle. This model has been developed for predicting potential contamination due to condensation. Due to payload sensitivity, understanding the thermal and vapor migration into the payload fairing is crucial for making accurate real time launch/no launch decisions. Experimental test equipment capable of simulating and measuring these conditions is currently being designed and built in an effort to verify the analytical model.

The purpose of the proposed design is to replicate actual scenarios of temperature and relative humidity differences between the ambient environment and the payload section. The design process and component selection was driven by cost, manufacturability, and design constraints which were met using calculations and estimations from various thermo-fluid laws and concepts. The proposed design is to create an inner control volume to replicate scaled ratios of different launch vehicle volume configurations. This test fixture is to be located within the larger external control volume simulating launch site atmospheric conditions. Each volume has independent environmental control systems capable of achieving steady state temperature and humidity conditions over a specified range. The inner control volume will be equipped with a controllable leak area and sensor array in order to induce and track the thermal and vapor migration into the inner control volume from the simulated environmental conditions during testing. A typical test procedure would include achieving steady state conditions in both control volumes, disabling the environmental control in the inner control volume, opening the vents of the test fixture to the surrounding environment and tracking the vapor and thermal migration into the inner control volume over time with a three dimensional sensor matrix. The data from the matrix of sensors with a calculated uncertainty will be collected in order to validate the original analytical model.

The use of standard parts, simple to manufacture custom parts, and accurate cost effective sensors is essential in achieving the design goals within the proposed budget. The external control volume is being designed to simulate a wide range of environmental conditions with an emphasis on maintaining the feasibility of the design, maximizing cost effectiveness while achieving experimental accuracy.

TFAWS-PT-008

NASA International Space Station Passive Thermal Control System Thermal Model Check-out

Laurie Carrillo, NASA Johnson Space Center, Houston, TX

ABSTRACT

The NASA International Space Station (ISS) Passive Thermal Control System (PTCS) Group performs reviews/check-outs of thermal models planned for distribution to other ISS participants. An example is a thermal model of a payload that will be launched via a SpaceX or JAXA vehicle and installed on the ISS. It is the responsibility of NASA ISS PTCS to maintain a database of received models, conduct checkout of the models received, prepare checkout reports, interact with the model developers to make required modifications, and deliver the model to the next destination. A model checkout process was developed based on an existing NASA approved Boeing ISS process. A NASA built template was prepared to streamline the checkout process, provide guidance to future model reviewers, and ensure consistency from one checkout to the next. The process in its current form has been utilized by NASA ISS PTCS on six payloads and is the intended check-out process for all upcoming payloads to be launched and installed on the ISS. This process is general enough that it can be adopted and applied to any thermal model review scenario. Thermal Desktop is currently the software used with the ISS Program utilizing a converted TRASYS model. Details of the check-out process with supporting examples are presented.

TFAWS-PT-009

Thermal Analysis of the Parachute System for the Low Density Supersonic Decelerator Project

Sandria Gray, NASA Jet Propulsion Laboratory

ABSTRACT

The thermal design and analysis of the experimental Supersonic Flight Dynamics Test (SFDT) vehicle is presented. The SFDT vehicle is currently being designed as a platform to help demonstrate key technologies for NASA's Low Density Supersonic Decelerator (LDSD) project. The LDSD project is charged by NASA's Office of the Chief Technologist (OCT) with the task of advancing the state of the art in Mars Entry, Descent, and Landing (EDL) systems by developing and testing three new technologies required for landing heavier payloads on Mars. The enabling technologies under development consist of a large 33.5 meter diameter Supersonic Ringsail (SSRS) parachute and two different types of Supersonic Inflatable Aerodynamic Decelerator (SIAD) devices – a robotic class, SIAD-R, which inflates to a 6 meter diameter torus, and an exploration class, SIAD-E, which inflates to an 8 meter diameter isotensoid. As part of the technology development effort, the various elements of the new supersonic decelerator system must be tested in a Mars-like environment. This is currently planned to be accomplished by sending a series of SFDT vehicles into Earth's stratosphere. Each SFDT vehicle will be lifted to a stable float altitude by a large helium carrier balloon. Once at altitude, the SFDT vehicles will be released from their carrier balloon and spun up via spin motors to provide trajectory stability. An onboard third stage solid rocket motor will propel each test vehicle to supersonic flight in the upper atmosphere. After main engine burnout, each vehicle will be despun and testing of the deceleration system will begin: first an inflatable decelerator will be deployed around the aeroshell to increase the drag surface area, and then the large parachute will be deployed to continue the deceleration and return the vehicle back to the Earth's surface. The SFDT vehicle thermal system must passively protect the vehicle structure and its components from cold temperatures experienced during the ascent phase of the mission as well as from the extreme heat fluxes produced during the supersonic test phase by the main motor plume and aeroheating. The passive thermal design approach for the SFDT vehicle relies upon careful and complex bounding analysis of all three modes of heat transfer - conduction, convection, and radiation - coupled with a tightly managed transient power dissipation timeline for onboard electronics components throughout all mission phases. This presentation will give an overview of this project and the thermal analysis of the parachute system.