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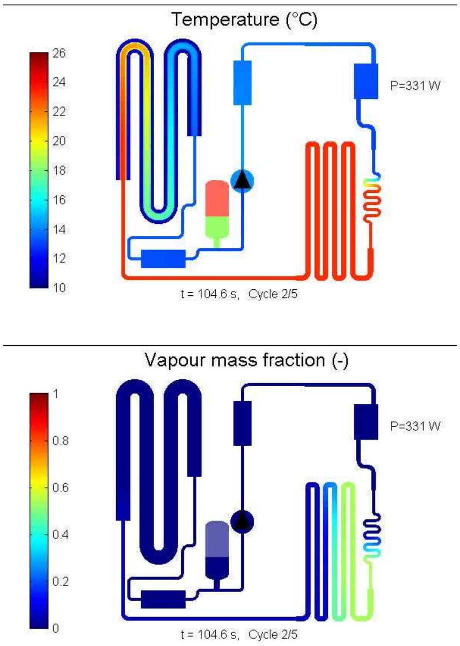

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Abstract

This document contains the presentations of the 27th European Space Thermal Analysis Workshop held at ESA/ESTEC, Noordwijk, The Netherlands on 3–4 December 2013. The final schedule for the Workshop can be found after the table of contents. The list of participants appears as the final appendix. The other appendices consist of copies of the viewgraphs used in each presentation and any related documents.
Proceedings of previous workshops can be found at http://www.esa.int/TEC/Thermal_control under 'Workshops'.

Please note that this document contains clickable hyperlinks which are shown as blue text.

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Programme Day 1

9:00 Registration

9:45 **Welcome and introduction**

Harrie Rooijackers (ESA/ESTEC, The Netherlands)

10:00 **Thermal Concept Design Tool** — Flux calculation results and the new tool presentation

Andrea Tosetto & Matteo Gorlani (Blue Engineering, Torino, Italy)
Harrie Rooijackers (ESA/ESTEC, The Netherlands)

10:25 **Evaluation of Heat Transfer Parameters from CFD for Use in TMM in Case of Gas Convection in Vented Cavities**

Christian Wendt (Astrium Space Transportation, Bremen, Germany)

10:50 **Introduction to Simulation Data Management**

Peter Bartholomew (MDAO Technologies, United Kingdom)

11:15 Coffee break in the Foyer

11:45 **EVATHERM for Early Validation of Thermal Control**

Fabrice Mena (Astrium SAS, France)

12:10 **Thermo-electrical Detailed Analysis**

François Mercier & B. Samaniego & V. Gineste & L. Gajewski & A. du Jeu (Astrium SAS, Toulouse, France)

12:35 **Correlating thermal balance test results with a thermal mathematical model using evolutionary algorithms**

Niek van Zijl & B. Zandbergen (Delft University of Technology, The Netherlands)
Bruin Benthem (Dutch Space B.V., The Netherlands)

13:00 Lunch in the ESTEC Restaurant

14:00 **Exchange of Thermal Models** — Challenges and Solutions

Stefan Kasper (Jena-Optronik GmbH, Germany)

14:25 **The KT Thermal Mapping Tool** — an semi-automated temperature transfer between structural and thermal models

Anton Zhukov & Markus Czupalla & Alexander Kuisl & Gerhard Bleicher & Winfried Gambietz
(Kayser-Threde GmbH, Müchen, Germany)

14:50 **Mapping nodal properties between dissimilar nodal representations of S/C structures using ESATAN-TMS**

Alexander Maas (Dutch Space, The Netherlands)

15:15 **MASCOT** — Thermal subsystem design

Luca Celotti & Riccardo Nadalini & Małgorzata Sołyga (ActiveSpace Technologies GmbH, Germany)
Volodymyr Baturkin (DLR Institut für Raumfahrsysteme, Germany)
Sergey Khairnasov & Vladimir Kravets (National Technical University of Ukraine, Ukraine)

15:40 Coffee break in the Foyer

16:00 **LHP MODULE SOFTWARE** — Application at System Level
Paul Atinsounon & David Valentini (Thales Alenia Space, France)

16:25 **Time dependent behaviour of pumped two-phase cooling systems** — Experiments and Simulations
Henk Jan van Gerner (NLR, The Netherlands)

16:50 **Study on the utilization of the FHTS extension of ESATAN-TMS for the thermal modeling of a bi-propellant satellite propulsion system**
Martin Schröder (OHB System AG, Germany)

17:15 **Thermal Modeling of CubeSats and Small Satellites**
Anwar Ali & M. Rizwan Mughal & Haider Ali & Leonardo M. Reyneri
(Department of Electronics and Telecommunications, Politecnico di Torino, Italy)

17:40 Social Gathering in the Foyer

19:30 Dinner in *La Toscana*

Programme Day 2

9:00 **E-THERM POLICY**

Thierry Basset & Patrick Hugonnot (Thales Alenia Space, France)

9:25 **ESATAN Thermal Modelling Suite** — Product Developments and Demonstration

Chris Kirtley & Henri Brouquet (ITP Engines UK Ltd, United Kingdom)

movies/media6

10:10 **SYSTEMA-THERMICA** — Launcher Case Set-up and Thermal Analysis

Timothée Soriano & Rose Nerriere (Astrium SAS, Toulouse, France)

10:55 Coffee break in the Foyer

11:20 **First Application of Esatan-TMS r6 Solids for a Launcher Upper Stage Thermal Model**

Harold Rathjen (Atrium, Bremen, Germany)

11:45 **Enhancement of ray tracing method for radiative heat transfer with new Isocell quasi-Monte Carlo technique and application to EUI space instrument baffle**

Lionel Jacques (Centre Spatial de Liège, Belgium)
Luc Masset & Gaetan Kerschen (University of Liège, Space Structures and Systems Laboratory, Belgium)

12:10 **Calculation of Optimal Solar Array Steering Laws for Temperature Critical Missions**

Andreas Brandl (Astrium GmbH Ottobrunn, Germany)
Jan-Hendrik Webert (Universität der Bundeswehr Müchen, Germany)

12:35 **BepiColombo MTM STM Thermal Test**

Scott Morgan (Astrium EADS, United Kingdom)

13:00 Closure

13:00 Lunch in the ESTEC Restaurant

Appendix A

Welcome and introduction

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Appendix B

Thermal Concept Design Tool

Flux calculation results and the new tool presentation

Andrea Tosetto Matteo Gorlani
(Blue Engineering, Torino, Italy)

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Abstract

During its lifetime the TCDT has evolved both through improvements suggested or required by users all over the ESA member states and enhancements as part of the development and maintenance contract with ESA.
The current release 1.6.0 of the TCDT is already available to the European Thermal Community and contains an internal flux calculator for TCDT models. This flux calculator has been validated through comparison of results with ESATAN-TMS r5.
The evolution of the tool that is now under development will be a portable stand-alone application, independent of Excel, that can be more easily integrated in existing workflows. Skilled engineers will be able to easily extend the tool with their only script, re-using the existing functionality, in order to perform their analysis in an easier way. To maximise the functionality available in the basic tool, participants are invite to discuss their ideas and suggestions with us directly during the breaks or contact us after the workshop.

Appendix C

Evaluation of Heat Transfer Parameters from CFD for Use in TMM in Case of Gas Convection in Vented Cavities

Christian Wendt
(Astrium Space Transportation, Bremen, Germany)

Abstract

The analysis of the convection in Ariane 5 launcher's vented cavities on ground and during ascent is important for the thermal control of the equipments and of the propellants during flight phase. For the according analysis of the upper stage, a lumped parameter Thermal Mathematical Model (TMM) has been established within ESATAN.

As an input, heat transfer parameters (HTPs) have been derived from two related Computational Fluid Dynamic (CFD) analysis cases, the so called hot and cold case. The methodology for evaluation of these HTPs from the CFD analysis is described for one and more gas nodes based on steady state results. For a representative launcher cavity with laminar/turbulent buoyancy influenced flow, a comparison is provided between the TMM results and the CFD results obtained with the commercial tool ANSYS Fluent. Exact agreement is achieved between TMM and CFD for the hot and the cold case. Deviations for the analyzed intermediate cases turned out to be less than 5K in case of a one gas node TMM and less than 3K in case of a seven gas node TMM.

Appendix D

Introduction to Simulation Data Management

Peter Bartholomew
(MDAO Technologies, United Kingdom)

Abstract

This presentation will give an introduction to the topic of Simulation Data Management. This is currently a hot topic in industrial areas such as automotive or aeronautics, however, for the space thermal analysis community it is still quite new. The objective of the presentation is to give an overview of the field and to stimulate discussion about how space thermal analysis models could be managed and how the analysis tools could be developed to facilitate this.

Appendix E

EVATHERM for Early Validation of Thermal Control

Fabrice Mena
(Astrium SAS, France)

Abstract

Commercial telecommunication programs require a more and more demanding reduced schedule for the integration & validation phases of the satellites.
The validation of the Thermal Control System (TCS) which is mission dependant represents a major activity which drives the schedule competitiveness. This aspect becomes a key challenge especially when the satellite is a prototype such as Alphabus PFM platform or Neosat, with new features and enhanced architectures, implying higher technical risks to be removed at the earliest in the program.
The analysis of a typical satellite Assembly, Integration & Test sequence gives the evidence that considering the *extensive system testing in clean room at ambient pressure & temperature*, there is an opportunity to perform an *early validation and correlation* of the satellite Thermal Mathematical Model (TMM) prior to the Thermal Vacuum & Thermal Balance testing.
Thus, the presentation will give an overview of the Evatherm method for Early Validation of the Thermal Control, developed together with ESA in the frame of Artes 3-4 and implemented in a real industrial and challenging Satcom program as Alphasat.
This engineering approach and associated software tools allow first to perform temperatures predictions and model correlation of the satellite system through testing in clean room, all along the AIT sequence, and second to implement Real time, Innovative & Improved Analysis methods (IAMITT) during the satellite Thermal Vacuum test itself.
The benefit in terms of thermal architecture performances justification or workmanship verification has been substantial and the methodology and the tools are now intended to be used as a standard.

Appendix F

Thermo-electrical Detailed Analysis

François Mercier B. Samaniego V. Gineste L. Gajewski A. du Jeu
(Astrium SAS, Toulouse, France)

Abstract

An important part of the power system engineering work is deeply linked to the thermal aspects of the various power components like batteries and solar panels. With the help of an internally developed coupled thermo-electrical solver, previously untried detailed analyses on various power systems were performed in Astrium, stemming interesting results.
The wide-spread Thermisol thermal solver in the Systema software suite was extended with a power add-on. The principle was to add an electrical layer through dedicated nodes complementary to the existing thermal nodes. It allowed the power users to code electrical systems and user components on the same environment as the existing Thermisol codes.
This new solver was applied for a full satellite power system analysis. The coupling with the thermal aspect allowed the re-use of thermal files and designs to prepare the analysis. An electrical layer composed of the user components of a classical power system (battery, solar array, power regulation and distribution) was added to perform fully coupled thermo-electrical analysis, adding higher accuracy to the battery, solar array and regulation modeling.
In the frame of an ESA study to investigate on solar array thermal / electrical imbalance in power systems equipped with MPPT, in-depth modeling of solar panels were also performed on both electrical and thermal aspects. This allowed cell level analysis for very fine phenomenon like the local cell gradients created by dissipation of back panel diodes and harness during orbit cycles, sensitivity studies to default or accurate local and global shadowing analyses.
The solver was also included in a software loop with coupled SAS/MPPT hardware for validation testing.

Appendix G

Correlating thermal balance test results with a thermal mathematical model using evolutionary algorithms

Niek van Zijl B. Zandbergen
(Delft University of Technology, The Netherlands)

Bruin Benthem
(Dutch Space B.V., The Netherlands)

Abstract

The results of a series of thermal balance tests have been correlated with a thermal mathematical model. Three different optimization algorithms have been used for this: Monte Carlo simulation, Genetic Algorithm and Adaptive Particle Swarm Optimization. Based on a correlation criterion that minimizes the temperature difference between tests and model, the correlation can be optimized. APSO proved to be most useful, for its ability to optimize both locally and globally, its ability to search in a continuous search space, and its fast convergence. In this research, an average residual error of only 1.1°C was found. In general, optimization algorithms are feasible for thermal balance test results correlation. Comparing to manual correlation, optimization algorithms take less time, yield better results since they scan the entire search space, and are more flexible since several uncertain parameters can be varied at the same time. However, optimization techniques tend to find mathematical solutions rather than physical solutions, so boundaries on the parameter space are needed, for example from other tests. Even though this research indicates a good correlation, the set-up was relatively small (only 129 nodes and 24 relevant temperature measurements and comparisons) and comprehensible. For larger (satellite) test programs, the thermal network might be less easily understood and contain more unknowns and uncertainties. In that case a correlation using optimization techniques might be less optimal. Some engineering judgement of the thermal engineer will always be needed.

Note: An article explaining the method in more detail is included behind the presentation.

Appendix H

Exchange of Thermal Models
Challenges and Solutions

Stefan Kasper
(Jena-Optronik GmbH, Germany)

Abstract

This presentation deals with the various challenges of exchanging thermal models that can be encountered by:

- use of different thermal software tools
- use of different ESATAN-TMS versions
- use of different modeling rules / model design standards
- differences in thermal modeling specification documents

Appendix I

The KT Thermal Mapping Tool
an semi-automated temperature transfer between structural and thermal models

Anton Zhukov Markus Czupalla Alexander Kuisl Gerhard Bleicher
Winfried Gambietz
(Kayser-Threde GmbH, Müchen, Germany)

Abstract

The analysis of the thermo-opto-mechanical performance of optical instruments is a complex and time consuming process. It spans across multiple disciplines and multiple tools (e.g. ESATAN, NASTRAN, ZEMAX) which are not designed to interface with one another.
To allow precise end-to-end thermo-opto-mechanical analyses of instruments, without the loss of data, KT establishes a software suite (MULTIPAS), which inherently connects the thermal, structural and optical tools.
An important part of the MULTIPAS software suit is the Thermal Mapping Tool (TMT) providing the link between the thermal and structural model. The tool realize an automated temperature mapping process based on in-house interpolations routines and has the ability to handle mismatching meshes of the thermal and structural models.
To preserve thermal boundaries between the parts a recognition of single parts is built in the TMT, allowing to map geometrically adjacent but thermally decoupled parts correctly. Further, edge effects are covered in a way that guarantees no extrapolations at the edges, preserving the temperature range prescribed by the thermal model. A built in batch mode allows for handling of thousands of time steps, opening the door to transient stability analyses of entire orbits.
Demonstration of the TMT functionality, results from application experience will be presented and discussed in the presentation. Further, conclusions shall be presented and discussed for the build of GMMs which are to be used as mapping "templates".

Appendix J

Mapping nodal properties between dissimilar nodal representations of S/C structures using ESATAN-TMS

Alexander Maas
(Dutch Space, The Netherlands)

Abstract

When multiple parties are involved in a single project, they often use different (thermal) models to represent a particular part or structure. As the nodal distribution is not always the same, it can be difficult to exchange data (e.g. flux distributions and temperature profiles) from one party to another. Clever use of a standard ESATAN-TMS tool can simplify the mapping of nodal data from one nodal representation to another for some of these applications, i.e. where the geometric models are sufficiently similar such that the conductive interfaces between the different node systems can be calculated by ESATAN-TMS. By using the conductive area calculation tool, the contact area between the different nodal representations can be determined. By means of area averaging, any nodal parameter can be projected onto the other nodal representation system. This process requires a few manual steps that can be performed automatically by means of a script. The method has been successfully applied in a detailed S/A plume flux analysis, where plume flux distributions determined in one nodal system were applied to a more detailed model to determine the S/A temperatures. This application is used as an example to show all required steps.

Appendix K

MASCOT
Thermal subsystem design

Luca Celotti Riccardo Nadalini Małgorzata Sołyga
(ActiveSpace Technologies GmbH, Germany)

Volodymyr Baturkin
(DLR Institut für Raumfahrsysteme, Germany)

Sergey Khairnasov Vladimir Kravets
(National Technical University of Ukraine, Ukraine)

Abstract

MASCOT is a lander built by DLR, embarked on JAXA's Hayabusa-2, a scientific mission to study the asteroid 162173 1999 JU3. It is a small lander, less than 300x300x200mm?, with onboard payloads (camera, magnetometer, radiometer and IR spectrometer), developed in collaboration by DLR and CNES. MASCOT lands on the asteroid surface, after being released by Hayabusa-2 from a very close position above the asteroid surface, and investigates the asteroid surface. The thermal design of the lander represents one of the main challenges in the whole project because of multiple constraints, depending on the mission phase, mass, power and free space available.

MASCOT, notwithstanding its small size, is equipped with redundant heat-pipe system, MLI blanket, heaters. The thermal design of the lander has been chosen after a trade-off phase concerning the technology which could suit better the opposing requirements of the mission: low heat exchange between the lander and the exterior (including the main spacecraft) in cruise, possibility to transfer all the heat dissipated by the internal paylaods and electronic boards during operations on asteroid surface. After selecting the heat-pipe technology as baseline, a development phase was undertaken by the partners both in terms of manufacturing, testing, thermal characterization phase and analitical modelling in order to match the thermal requirements.

Heaters are used to assure the survival of the most delicated parts of the lander during cold cruise phases: the battery cells (only primary battery on-board), the electronic boards and the main payload. Strict requirements are given by the main spacecraft in terms of maximum power available to heat the lander during cruise. MLI blankets are used where the available space allows it, e.g. to extra insulate the Ebox from the rest of the lander creating a „hot compartment" and between the lander and the main spacecraft to reduce the heat exchange with it during cruise below the given limits. The whole thermal concept in all its parts undertook a detailed modelling phase in parallel to an experimental phase in vacuum chamber to improve the model and to qualify the system.

MASCOT thermal design is here presented through the following points:

- MASCOT as part of HY-2 mission: mission, constraints, challenges
- Challenging thermal requirements
- Main thermal strategy and trade-offs: available technologies, constant conductance heat-pipes
- Thermal design
- Vacuum chamber testing
- Thermal model results
- Conclusions and future steps

Appendix L

LHP MODULE SOFTWARE

Application at System Level

Paul Atinsounon David Valentini
(Thales Alenia Space, France)

Abstract

Loop Heat Pipes (LHPs) are more and more used for spacecraft thermal control thanks to its performances and ability to transport heat load on a long distance.
In the frame of CSO program, LHPs are implemented on Visible and Infra-Red Detection Sub-assemblies.
In order to simulate LHPs behaviour at system level, specific software was developed by Astrium / Thales Alenia Space under CNES and ESA fundings. The LHP Module is compatible with many thermal softwares and works as a sub-model of ESATAN-TMS Thermal Mathematical Model (TMM).
The objectives of the presentation are to describe briefly the LHP Module inputs/outputs and functional blocks. Main performances of Visible and Infra-Red Assemblies are simulated using the LHP Module. Breadboard test exploitations are compared with predictions in order to validate the LHP Module accuracy. The software limits and constraints will also be presented.

Appendix M

Time dependent behaviour of pumped two-phase cooling systems
Experiments and Simulations

Henk Jan van Gerner
(NLR, The Netherlands)

Abstract

Two-phase pumped cooling systems (see figure M.1) are applied when it is required to maintain a very stable temperature in a system, for example in the AMS02, which was launched with the space shuttle (in May 2011) and subsequently mounted on the International Space. However, a two-phase pumped cooling system can show complex dynamic behaviour in response to rapid heat load variations. For example, when the heat load is increased, a large volume of vapour is suddenly created, which results in a liquid flow into the accumulator and an increase in the pressure drop. This will result in variations in the pressure and therefore temperature in the system, which are undesired. It is difficult to predict and understand this behaviour without an accurate dynamic model. For this reason, such a model has been developed by NLR. The model numerically solves the one-dimensional time-dependent compressible Navier-Stokes equations, and includes the thermal masses of all the components (see figure M.2 for an example). The model has been used for different projects, and the numerical results show an excellent agreement with experiments. During the presentation, I will discuss different pumped two-phase cooling systems, and a comparison between simulations and experiments.

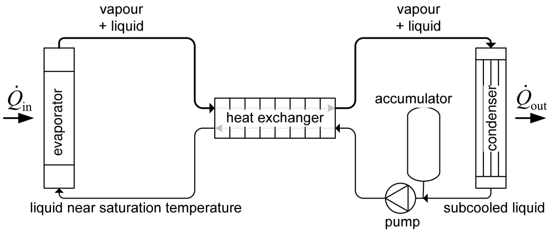

Figure M.1: Schematic drawing of a two-phase pumped cooling system

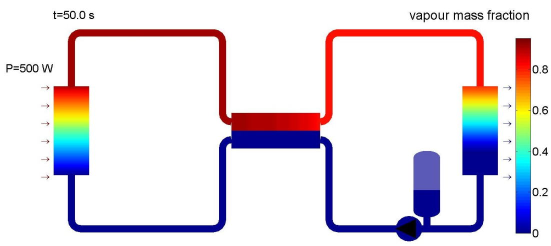

Figure M.2: Calculated vapour mass fraction

Appendix N

Study on the utilization of the FHTS extension of ESATAN-TMS for the thermal modeling of a bi-propellant satellite propulsion system

Martin Schröder
(OHB System AG, Germany)

Abstract

The presentation will contain the findings of my diploma thesis done in cooperation with OHB System AG. Its aim was to investigate if the FHTS extension of ESATAN-TMS could be used to model the fluid inside a bi-propellant chemical propulsion system with regard to the thermal control system. At first, a FHTS fluid library for propellants and pressurizing agents was implemented in order to model the fluids in the propulsion system accurately. After that, two simplified thermal models using the fluid library were developed, one for the pressure control assembly (PCA) and another for the propellant insulation assembly (PIA). For both models inputs from a reference geostationary telecommunication satellite were used. The presentation will mainly deal with the modeling of the effect of gas cooling by the expansion of Helium gas through the gas pressure regulator of the PCA. The solution found will be explained and the results of the simulations shown. Eventually several best practices and lessons learnt shall be presented with regard to the use of FHTS for propulsion systems.

Appendix O

Thermal Modeling of CubeSats and Small Satellites

Anwar Ali M. Rizwan Mughal Haider Ali Leonardo M. Reyneri
(Department of Electronics and Telecommunications, Politecnico di Torino, Italy)

Abstract

Recently universities and SMEs (Small and Medium Enterprises) have initiated the development of nanosatellites because of their low cost, small size and short development time. The challenging aspects for these satellites are their small surface area for heat dissipation due to their limited size. There is not enough space for mounting radiators for heat dissipation. As a result thermal modeling becomes a very important element in designing a small satellite. A generic thermal model of a CubeSat satellite is presented in this paper. Detailed and simplified thermal models for nanosatellites have been discussed. The detailed model takes into account all the thermal resistors associated with the respective layer while in the simplified model the layers with similar materials have been combined together and represented by a single thermal resistor. The thermal model of complete CubeSat has been presented. The proposed models have been applied to CubeSat standard nanosatellite called AraMiS-C1, developed at Politecnico di Torino. Thermal resistances measured through both models are compared and the results are in close agreement. The absorbed power and the corresponding temperature differences between different points of the single panel and complete satellite are measured. In order to verify the theoretical results, the thermal resistance of the AraMiS-C1 is measured through an experimental setup. Both values are in close agreement.

Detailed thermal model of the CubeSat panel from top to bottom is shown in figure O.1 and will be further explained in the presentation. Simplified thermal model of the CubeSat panel from top to bottom is shown in figure O.2 and will be further explained in the presentation.

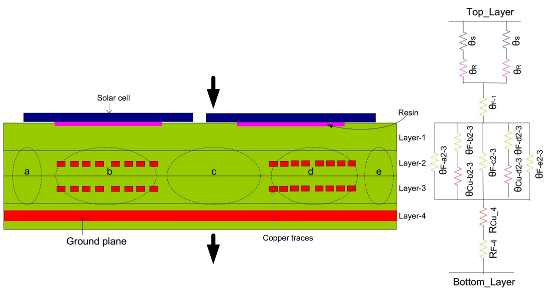

Figure O.1: CubeSat panel cross sectional view and detailed thermal model

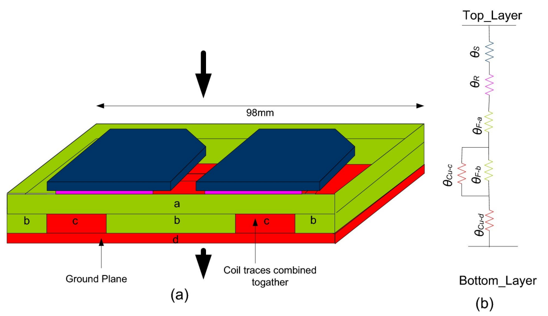

Figure O.2: Panel top to bottom cross sectional view and simplified model

Thermal model of the complete CubeSat is shown in figure O.3 and will be further explained in the presentation.

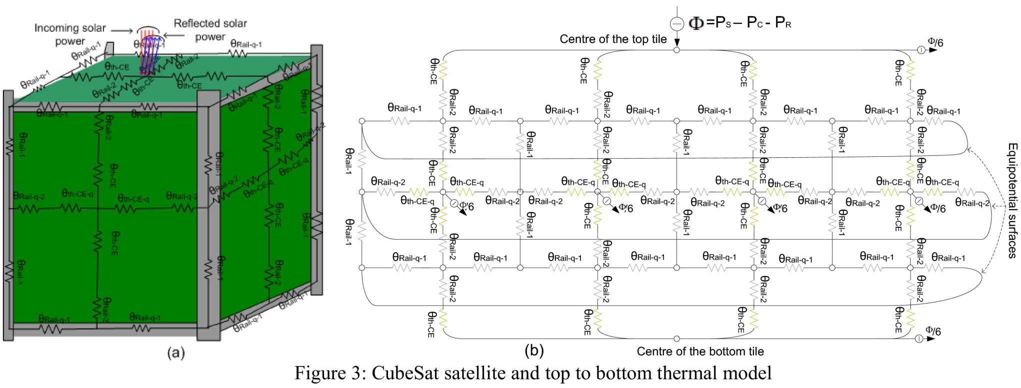

Figure O.3: CubeSat satellite and top to bottom thermal model

Appendix P

E-THERM POLICY

Thierry Basset Patrick Hugonnot
(Thales Alenia Space, France)

Abstract

In Thales Alenia Space - Cannes, we have a long experience and expertise, in thermal software development. Concerning this point, we work with external companies in particular with DOREA. The subject concerns the presentation, the demonstration of a new thermal software in TAS-Cannes (= e-Therm release 1.4.c), and the associated policy. This tool is funded entirely by TAS-Cannes and it should not have to be commercialised but freely distributed.
Then, we will to talk about industrialization strategy especially based on using of our thermal software and on the integration of expert tools: Pre-processing, Orbitography module, 2D-3D Conductive module, Radiative module, Solver module, Thermal model reduction tool, PTA (which is a tool dedicated to preliminary phases and very well adapted to the telecom program), Post-processing. The general aim of these evolutions is to improve and standardize the analysis process, in order to gain in cost, quality and input/output traceability. This calculation chain is entirely compatible with thermal analysis COTS, main CAD and mechanical tools, thanks to powerful interfaces. These modules have been successfully used on following programs : Apstar, Yamal, W6A, O3B, Iridium Next, 8WB, TKM, CSO ...
Moreover, to improve quality and reliability of the dynamic spacecraft simulator and for performance reasons, TAS-Cannes chooses e-Therm to be the thermal real-time simulator engine based on the thermal mathematical model (TMM) provided by thermal analysis team. External powers calculator and temperatures resolution from internal e-Therm core module have been successfully improved to fit the real-time constraints. Parallelisation has been largely used to make the calculation most reactive in order to fit as much as possible the physics behaviour. New SCSIM based on TMM has been successfully validated on Alphasat (@bus platform) and O3B Networks satellite.
On another hand and to answer customer's needs, TAS-Cannes needed to provide a real time payload configuration simulator. A new session has been implemented into e-Therm. This session provides for each daily configuration a detailed thermal cartography for each channels based on powerful post-processing outputs (Barchart, CAD view ...). This session will be used on 8WB program planned to run all over the satellite lifetime.
In parallel of industrialization strategy, we develop a strategy of openness of e-Therm by distributing software free of charge to TAS-Toulouse for antenna applications, TAS-Turin for infrastructures and instruments and more generally to TAS-Group and to others companies.
Furthermore, e-Therm can be used for concurrent design facility applications, and to other fields in physics: electronic board thermal behaviour calculation, ESD simulation on geostationary satellite.

Appendix Q

ESATAN Thermal Modelling Suite
Product Developments and Demonstration

Chris Kirtley Henri Brouquet
(ITP Engines UK Ltd, United Kingdom)

Abstract

ESATAN-TMS provides a complete and powerful integrated thermal modelling environment. ESATAN-TMS r6 sees a major evolution of the product, with advances to its geometry modelling and 3D visualisation capabilities. This presentation outlines the developments going into the new release of the product.
A demonstration of ESATAN-TMS r6 will be given, building a model to demonstrate the new functionality.

Appendix R

SYSTEMA-THERMICA
Launcher Case Set-up and Thermal Analysis

Timothée Soriano   Rose Nerriere
(Astrium SAS, Toulouse, France)

Abstract

Thermal analyses of launchers have specific constraints which have been integrated in the up-coming release 4.7 of SYSTEMA-THERMICA. This presentation illustrates through a demonstration the newly integrated features allowing a launcher case set-up.

A new catalogue of volume primitives, required for modeling the launcher, has been added. The software handles the generation of external coating and internal bulk nodes and also automatically switches the activities according to contact detections.

On the mission aspects, launcher trajectories and attitudes are usually defined by discretized data expressed in complex inertial frames (synchronization of rotational frames related to the launcher base position).

Once the geometrical model and mission are set-up, the thermal analysis can start.

The thermal analysis of the previously defined launcher case requires the computation of the conduction into the volume structures as well as radiative exchanges between external coatings, planet Albedo and IR, solar and aero-thermal fluxes.

The presentation focuses on the volume management and on the new aero-thermal flux module which integrates an atmospheric model.

Besides, the new SYSTEMA version 4.7 has new post-processing features: from the generation of mission log data to the comparison of different thermal cases and margins set-up, results based on the launcher case are exploited.

Appendix S

First Application of Esatan-TMS r6 Solids for a Launcher Upper Stage Thermal Model

Harold Rathjen
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Abstract

The development of this new feature of Esatan was driven by the need for thermal software that allows a volumetric modeling for heavy launcher structures and the applied thermal protection with thicknesses of up to several cm. This presentation assesses the first experiences with this tool applied on an existing upper stage model created within the Ariane 6 development program. Due to the early project status with a limited number of nodes this model is considered a good test. The advantages in particular of the automatic conductor generation (ACG) in comparison with the previous shell approach will be discussed.

Appendix T

Enhancement of ray tracing method for radiative heat transfer with new Isocell quasi-Monte Carlo technique and application to EUI space instrument baffle

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Abstract

The finite element method (FEM) is widely used in mechanical engineering, especially for space structure design. However, FEM is not yet often used for thermal engineering of space structures where the lumped parameter method is still dominant. Radiative exchange factors (REFs), used to calculate radiative thermal exchanges in space, are usually computed through Monte Carlo ray-tracing. Due to the large number of elements composing a FE model, the computation of the REFs is prohibitively expensive. In the frame of a global approach, several research axes will be investigated to reduce the computational effort of the REFs with FEM. The first one focuses on accelerating the convergence and enhancing the accuracy of the ray-tracing process to decrease the number of rays required to achieve a given accuracy. The developments of the new Isocell quasi-Monte Carlo ray tracing method are presented. Based on Nusselt's analogy, the ray direction sampling is carried out by sampling the unit disc to derive the ray directions. The unit disc is divided into cells into which random points are then generated. The cells have the particularity of presenting almost the same area and shape. This enhances the uniformity of the generated quasi-random sequence of ray directions and leads to faster convergence. This Isocell method has been associated with different surface sampling to derive the REFs. The method is benchmarked against ESARAD, the standard thermal analysis software used in the European aerospace industry. Various geometries have been used. In particular, one entrance baffle of the Extreme Ultraviolet Imager (EUI) instrument developed at the Centre Spatial de Liège in Belgium is used. The EUI instrument of the Solar Orbiter European Space Agency mission and will be launched in a Sun-centered (0.28 perihelion) orbit in 2018.

Appendix U

Calculation of Optimal Solar Array Steering Laws for Temperature Critical Missions

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Abstract

For the Solar Orbiter and Bepi Colombo missions it is required to steer the solar arrays of the Spacecrafts in such a way that sensitive parts (like solar cells) do not exceed a maximum temperature, while keeping the electric power output as high as possible. This is usually done by adapting the sun aspect angle of the array in dependency of the actual heat input from the sun and if present from the planet.

In this presentation a fast and accurate method is discussed in which the optimized solar array rotation angles at each orbit position are calculated by a modified iteration-scheme with a detailed solar array thermal model.

With the developed iteration scheme it became possible to limit the total number of time consuming calculations of the time dependent radiation exchange factors to a minimum without losing the stability of the scheme. A further decrease of computational time was achieved by splitting the radiation calculation into sub-processes. Those have been distributed among the available computers, leading to an efficient parallelization of the radiation calculations.

Appendix V

BepiColombo MTM STM Thermal Test

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Abstract

BepiColombo is a joint ESA/JAXA mission to Mercury, and will provide the best understanding of the planet to date. Mercury's proximity to the sun has called for significant thermal design work on the spacecraft, with many new technologies being developed specifically for the project. This in turn has demanded a large amount of spacecraft testing and validation. This presentation will describe the Mercury Transfer Module (MTM) system level STM thermal test, detail the specific challenges faced, and report the results and the lessons learned from the correlation of the associated thermal model.

Appendix W

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