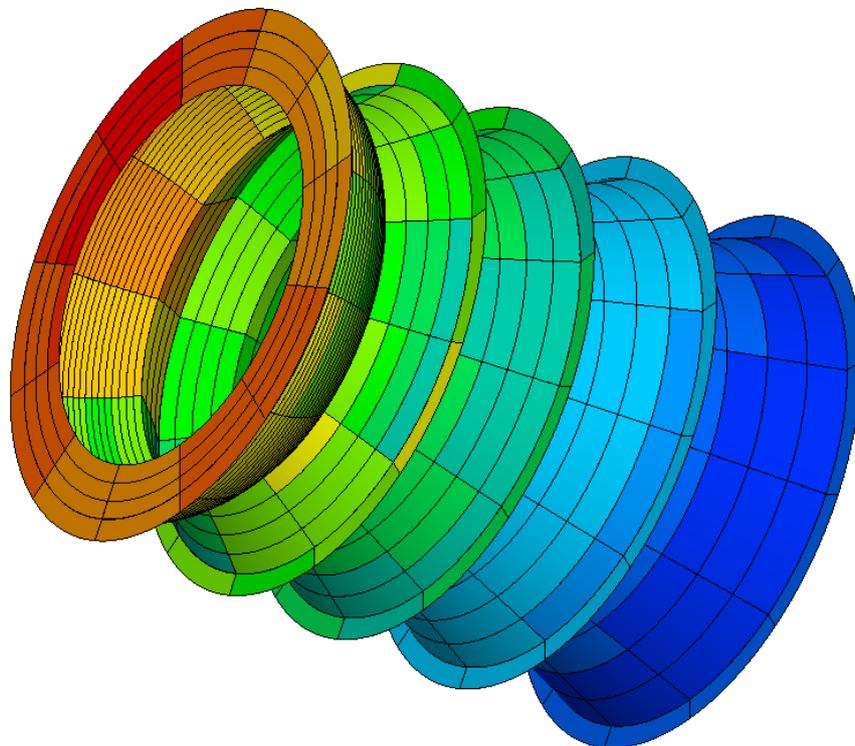


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Proceedings of the
23rd European Workshop
on
Thermal and ECLS Software

ESA/ESTEC, Noordwijk, The Netherlands

6–7 October 2009



courtesy: DLR German Aerospace Center, Institute of Planetary Research

European Space Agency
Agence spatiale européenne

Abstract

This document contains the minutes of the 23rd European Workshop on Thermal and ECLS Software held at ESA/ESTEC, Noordwijk, The Netherlands on 6–7 October 2009. It is intended to reflect all of the additional comments and questions of the participants. In this way, progress (past and future) can be monitored and the views of the user community represented. 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’.

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Programme Day 1

- 9:00 Registration
- 9:45 **Welcome and introduction**
Harrie Rooijackers (ESA/ESTEC, The Netherlands)
- 10:00 **Progress of the CIGAL2 distribution project**
Thierry Basset & Jean-Paul Dudon (Thales Alenia Space, France)
François Brunetti (DOREA, France)
- 10:30 **Heat shield thermal sensitivity analysis**
Matteo Gorlani (Blue Engineering, Italy)
Valter Perotto (Thales Alenia Space, Italy)
- 11:00 Coffee break in the Foyer
- 11:30 **TMRT — A thermal model reduction tool**
Mathieu Bernard (EADS Astrium, France)
Thierry Basset (Thales Alenia Space, France)
Sandrine Leroy & François Brunetti (DOREA, France)
James Etchells (ESA/ESTEC, The Netherlands)
- 12:00 **GENETIK — Genetic algorithm for the sizing cases research**
Hélène Pasquier & Stéphane Clouet (CNES, France)
- 12:30 **SYSTEMA**
Marc Baucher (EADS Astrium, France)
- 13:00 Lunch in the ESTEC Restaurant
- 14:00 **THERMICA – THERMISOL**
Timothée Soriano (EADS Astrium, France)
- 14:30 **ESATAN Thermal Modelling Suite — Product developments**
Henri Brouquet (ITP-UK, United Kingdom)
- 15:00 **ESATAN Thermal Modelling Suite — Demonstration**
Henri Brouquet (ITP-UK, United Kingdom)
- 15:30 Coffee break in the Foyer
- 16:00 **Methods for solving linearized networks in satellite thermal analysis**
Martin Altenburg & Johannes Burkhardt (EADS Astrium, Germany)
- 16:30 **Herschel experience on modelling and verification of active heater control**
Savino De Palo & Marco Compassi (ThalesAlenia Space, Italy)
Claudio Damasio (ESA/ESTEC, The Netherlands)
- 17:00 **Thermal model and analysis of the BELA transmitter Stavroudis baffle in Mercury orbit**
Simone Del Tugno & Gabriele Messina (DLR, Germany)
- 17:30 Social Gathering in the Foyer
- 19:30 Dinner in *Het Zuiderbad*

Programme Day 2

- 9:00 **Thermal design for an asteroidal lander**
Riccardo Nadalini (Active Space Technologies, Germany)
- 9:30 **TCDT — Distribution and maintenance**
Andrea Tosetto & Matteo Gorlani (Blue Engineering, Italy)
Harrie Rooijackers (ESA/ESTEC, The Netherlands)
- 10:00 **A thermal/structural mapping tool for thermo-elastic distortion analysis**
Daniel Wild (EADS Astrium, United Kingdom)
- 10:30 **Updates to the SINAS tool for mapping of lumped parameter temperatures onto a structural FE models**
Simon Martin & James Etchells & Simon Appel (ESA/ESTEC, The Netherlands)
- 11:00 Coffee break in the Foyer
- 11:30 **ESATAP 2.0.0 — Status and evolution of developments dedicated to thermal end users**
Alain Fagot & François Brunetti (DOREA, France)
Harrie Rooijackers & Hans Peter de Koning (ESA/ESTEC, The Netherlands)
- 12:00 **Final validation phases of the IITAS project for Industrial Implementation of STEP-TAS**
Eric Lebègue (CSTB, France)
Hans Peter de Koning (ESA/ESTEC, The Netherlands)
- 12:30 **Mathematical models for the Columbus engineering support team**
Savino De Palo & Gaetana Bufano & Albina Quaranta (ThalesAlenia Space, Italy)
Marco Bruno (Sofiter System Engineering, Italy)
- 13:00 Lunch in the ESTEC Restaurant
- 14:00 **On orbit performance of the EuTEF thermal control system — 1 Year on board the ISS**
Alberto Franzoso & Marco Molina & Paolo Ruzza & F. Tominetti & M. Grilli (Carlo Gavazzi Space, Italy)
- 14:30 Closure

Day 1

Tuesday 6th October 2009

1.1 Welcome and introduction

H. Rooijackers (ESA/ESTEC) welcomed everyone, outlined the main goals of the workshop, and reminded everyone about the 2010 ICES conference to be held in Barcelona. (See [appendix A](#))

1.2 Progress of the CIGAL2 distribution project

JP. Dudon (Thales Alenia Space) described the developments that had been made to the CIGAL2 package since it had been released to the community at the previous workshop. He outlined the changes already implemented in the Radiative and Conductive modules, and the future use of a third party meshing package. F. Brunetti (DOREA) then gave a video demonstration of the new pre- and post-processing features. (See [appendix B](#))

T. Soriano (EADS Astrium) asked whether the Radiative module took specularly into account. JP. Dudon told him that specularly was handled.

S. Price (Astrium UK) had noticed that the presentation had featured geostationary spacecraft, and asked whether it was also possible to simulate non-Earth missions, such as to Mars or Mercury, or to have complex trajectories. JP. Dudon replied that the “orbitography” graphical tool could only show Earth orbiting satellites, but the rest of the software was able to handle more complex missions. Only Earth-based missions were implemented in the “orbitography” module.

1.3 Heat shield thermal sensitivity analysis

M. Gorlani (Blue Engineering) presented the basic requirements for the Solar Orbiter mission, and the challenges presented by the heat shield analysis, and how stochastic techniques had been applied to identify interesting cases. He showed that the results obtained by using percentile bounds were not the same as those obtained for $\mu \pm 3\sigma$ bounds on a Gaussian distribution, even though both cases covered a 99.7% confidence interval of probable outcomes. (See [appendix C](#)) There were no questions.

1.4 TMRT — A thermal model reduction tool

M. Bernard (Astrium) presented the rationale behind the development of a common thermal model reduction tool. Thales Alenia Space and Astrium already had in-house tools but were not in a

position to commercialise them. With support from the Agencies, both companies wanted to harmonise the tools that they already used internally and with their sub-contractors. He outlined the model reduction process, and described the method of designating nodes to be kept, to be grouped or to be suppressed and how this was expressed in the matrix equations. S. Leroy (DOREA) then gave a live demonstration of using the TMRT to reduce a simple 10-node model into a 3-node model. (See [appendix D](#))

HP. de Koning (ESA/ESTEC) commented that from his own experience, it was very easy to make mistakes during model reduction, and asked whether there were any diagnostics in the software to check for correct configuration. S. Leroy confirmed that there were diagnostic checks in the software. M. Bernard said that there were many consistency checks made between the detailed and the reduced models, and that any diagnostic messages were output to file, with a summary.

HP. de Koning asked whether the system was able to handle sub-models. M. Bernard admitted that there were currently restrictions on the use of sub-models. The module importing the model only handled top-level models, and there were limits on the use of node variables. The model reduction used matrix inversion, based on numerical node numbers, and was not set up to handle symbolic node representation. To simplify the development, the matrix needed to contain simple node numbers only. The \$CONDUCTORS blocks were also rewritten based on a purely numerical basis.

D. Battaglia (Thales Alenia Space) asked whether, in the frame of the checks made on the compatibility of the detailed and reduced models, there was any correlation of the heat loads. M. Bernard replied that the same format was used for the output produced by both the detailed and the reduced models, so the user could import both the detailed and the reduced results into post-processing tools for comparison. The experience with telecom satellites had been that the difference between the detailed and reduced models was less than 1°C for the nodes of interest.

S. Vey (ESA/ESTEC) had seen that the presentation showed a display of the reduced geometrical model, and asked whether there was a way to export the reduced GMM corresponding to more complex models. M. Bernard explained that for complex models in ESARAD or THERMICA it was necessary to create groups manually and to simplify the complexity of the geometry. This functionality was not implemented in the TMRT. The TMRT was intended to be used to produce a reduced list of couplings, and to transform node numbers from the detailed model into equivalent node numbers in the reduced model, and not to produce a simplified geometry.

1.5 GENETIK — Genetic algorithm for the sizing cases research

H. Pasquier (CNES) described the basic principles of genetic algorithms, and how they could be applied to thermal design, and how they had been integrated into the analysis pipeline that included CONDOR, GAETAN, and ESATAN. (See [appendix E](#))

M. Gorlani (Blue Engineering) asked how many cases had been run for the analysis campaign shown in the presentation. H. Pasquier said that the thermal chain was run 1000 times, so a lot of calculations were needed during the simulations. They had set up a library in order to keep all of the results in memory, make sure that the same run was not done twice, and therefore optimise the number of calculations.

M. Gorlani asked whether the simulation was used only to find the worst cases, or whether it was used to help with design optimisation. H. Pasquier answered that it had only been used to find the worst cases for a satellite mission.

HP. de Koning (ESA/ESTEC) asked whether the method was parallelisable. H. Pasquier confirmed that it was, but had not started implementation.

HP. de Koning asked whether the algorithm could also be used for optimisation based on extreme cases, or on hot and cold gradients. H. Pasquier said that it was possible to do lots of things with GAETAN, so it depended on what criteria were defined. The parameter of interest was defined at the start of each run. There was a single objective per run.

JP. Dudon (Thales Alenia Space) asked whether the new version of the software would allow users to choose the number of mutations carried over into the next generation. H. Pasquier said that for mutations there would only be one choice, but for the crossover selection the user would be able to specify more. Even with GENETIK it was important to have a user who understood the system, and who could therefore choose the evolution parameters appropriately.

P. Zevenbergen (Dutch Space) asked whether it was possible to encounter convergence problems using genetic algorithms. H. Pasquier said that it was always possible, yes, but that was what they were trying to avoid by developing the protocol. The idea was to do a very big simulation, and to have a large amount of data, and then see whether changing certain parameters helped the system to converge faster. The user needed to keep a critical view on the protocol.

G. Jahn (Astrium GmbH) commented that it was possible for there to be a local optimum, and this could be avoided if the charts could show a complete spectrum between red and blue, rather than simply good child and bad child. Using the complete spectrum could save one step in the protocol. H. Pasquier admitted that they only had two colours in the GAETAN software and could therefore only show whether a case was good or bad.

1.6 SYSTEMA

M. Baucher (EADS Astrium) described the recent release history of SYSTEMA, and showed how the geometry, kinematics and trajectory aspects of a mission could be changed independently of each other to build up the overall analysis. This avoided most of the recalculation required in a more sequential system. SYSTEMA had recently implemented a means of introducing symbolic variables into the models, which could then be changed as required for different analysis cases. (See [appendix F](#))

T. Tirolien (ESA/ESTEC) asked about the new variable feature, and how it could be used in parametric studies: was there a way to define a parameter with a range and step value? M. Baucher said that the user could now define a parameter in the SYSTEMA models, and then run THERMICA and THERMISOL using particular values. T. Tirolien supposed that it was therefore necessary to provide a script to set the parameter and run the script as part of the analysis chain. He asked whether this parametric capability applied to any parameter, such as specularity. M. Baucher said that it would be possible to vary the specularity. They were still learning how to make the best use of this new capability, and would be looking at how to provide this as a step in the analysis chain. Any value that could be edited in SYSTEMA could be replaced by such a parameter.

M. Gorlani (Blue Engineering) asked about the strategy for using these parameters. Were they simply a means of providing a difference in settings in related models, or did they provide something more? M. Baucher answered that today, in order to modify an element, the user needed to edit the input of configuration files. The parameter feature allowed the user to specify a symbolic value that could be changed without changing the models. T. Soriano (EADS Astrium) explained that the goal was to allow the user to be able to specify a set of values in a file, and run the model many times without needing to go back into the system or edit files. The idea was to have a parametric mission with a set of parametric values so there would be no need to re-edit the system every time. M. Gorlani understood that the user would be able to provide a file containing parameter values, but would not be able to specify range or step values. T. Soriano said that the

user could use external tools to generate these values, and then run the parameter cases without needing to change the modules. M. Gorlani said that he could just provide these values in the input files. T. Soriano explained that the problem with editing directly in the input files, or generating the input files, was that it required tools which knew about the syntax of the input files. By having a simple parameter file containing just a list of parameter names and values, there was no longer any dependency on a specific input format for a specific version of the tools. Therefore the user would not need to change any local tools when moving from SYSTEMA version 4.2.2 to version 4.2.3.

HP. de Koning (ESA/ESTEC) asked whether POSTHER was included as part of SYSTEMA. T. Soriano said that it was provided with THERMISOL.

HP. de Koning wanted to avoid any confusion in the user community, and emphasized that STEP-NRF was included within STEP-TAS, and was not a separate format, so the standard should only be referred to as "STEP-TAS".

T. Tirolien had noticed that the demonstration had shown the camera being locked onto both the satellite and the Earth, and wanted to know whether it was possible to set the camera to look from the Earth to the spacecraft, or from the Sun to the spacecraft. M. Baucher said that these camera modes were not available in the current version, but would be available in version 4.3.4.

1.7 THERMICA – THERMISOL

T. Soriano (EADS Astrium) presented some new features in the latest versions of THERMICA and THERMISOL. THERMICA now offered the possibility of reporting and setting threshold values for percentage line sum error to improve the accuracy of the ray tracing. Changes had also been made to the conductive coupling calculations. THERMISOL now provided more extensions to the MORTRAN language to make life easier for the user. To allow easier sharing of models, a new converter was included that could generate "classical" MORTRAN that would be acceptable by both ESATAN and THERMISOL. (See [appendix G](#))

HP. de Koning (ESA/ESTEC) asked for some clarification of the ray tracing accuracy improvements. He asked whether they applied only to the REF calculations. He had understood that one method worked on the standard deviation, and the other worked on the line sum. T. Soriano explained that when you exported the radiative couplings, the sum of those couplings, a function of area and emissivity, should be equal to 1.0. In reality, you wouldn't find that because a "symmetrification" was applied to each pair of REFs to account for the limited number of rays used. The new method checked for this symmetry and fired more rays as required. HP. de Koning observed that it was possible to have a line sum of one, but still to have errors in the REFs. T. Soriano agreed, and said that was the reason why the standard deviation method step was always run as part of the accuracy control. HP. de Koning asked whether the new method also applied to fluxes. T. Soriano replied that there was no "symmetrification" available for the flux calculations, so the new method could not be used for fluxes.

1.8 ESATAN Thermal Modelling Suite — Product developments

H. Brouquet (ITP Engines UK) explained that this was the first presentation since the aerospace engineering group had been taken over by its new parent, and showed the company's "family tree" and where it fitted in the ITP worldwide presence. He then summarised the product changes that had been announced at the previous workshop, and what had been achieved in the two releases

since then. A lot of work had gone into transforming the old radiative analysis GUI into a more general `Workbench` that could be used with or without the space-based mission environment, and which therefore also replaced the old `PCESATAN`. (See [appendix H](#))

M. Gorlani (Blue Engineering) commented that during the Solar Orbiter analysis campaign, they had tried to build a fully parameterized GMM, but had encountered problems when loading and saving from the GUI where the parameters had been replaced by numerical values. H. Brouquet explained that it wasn't currently possible to transfer parameter variables from the GMM into the `ESATAN` file, and that they were output as numeric values. M. Gorlani stressed that the problem was that numerical values, and not parameter variables, were stored when the `ESARAD` model was saved from the `Workbench`, rather than when generating the `ESATAN` file. H. Brouquet replied that in theory all of the parameter variables should be retained when saving the GMM from the `Workbench`, but not when using the export model function.

M. Gorlani said that they had also experienced problems due to differences in the Linux version they were using and asked how the developers intended to support Linux. H. Brouquet said that the current policy was to support SuSE version 10 in the development environment, including testing and validation. Where possible, they would try to install different versions of Linux as virtual machines to reflect users' installations. For example, they had recently done some testing on CentOS-5.3 on 64-bit systems because that was what was in use at ESA. They would be trying to support more if needed. M. Gorlani said that A. Tosetto (Blue Engineering) would mention emulations of different systems during his presentation the next day. H. Brouquet admitted that they would not be able to support all platforms, but would now be focussing on PC-Windows and current versions of Linux used by customers.

1.9 ESATAN Thermal Modelling Suite — Demonstration

H. Brouquet (ITP Engines UK) gave a live demonstration of `ESATAN-TMS r2`, highlighting the new features. He conducted a "classical" thermal analysis, without orbit and space environment. He created a model of a base plate, two units with internal dissipation, and the non-geometric environment boundary node. He showed the creation of time-dependent values via the property editor, and the grouping of nodes to simplify conductor creation. At the end of the analysis he used `ThermNV` to post-process the temperature data and to have limits comparisons between different cases. (See [appendix I](#))

D. Battaglia (Thales Alenia Space) commented that the model shown had consisted of two units on a panel with conductors between them. He asked whether the value of the conductor had been temperature dependent, and whether it was output as a constant value or as a variable. H. Brouquet said that currently the conductor value would be exported to the GMM as a constant value, but would be exported to `ESATAN` as a local variable.

1.10 Methods for solving linearized networks in satellite thermal analysis

M. Altenburg (Astrium GmbH) presented the latest work on developing methods for converting thermal networks containing radiative (T^4) couplings into equivalent linear forms in an attempt to improve convergence and stability in the solutions. He described the use and results of both ordinary differential equation and quasi-analytical approaches. (See [appendix J](#))

HP. de Koning (ESA/ESTEC) asked whether any attempt had been made to use other solvers than those provided by MATLAB, such as one of the open source solvers. M. Altenburg answered that he had only experimented with the different MATLAB solvers, and had found some problems with all of them. He had found that ODE15s was the “best” solver. He had been in contact with MATLAB to try to resolve the problems, but did not have a complete solution yet. H. Rooijackers (ESA/ESTEC) commented that some solvers were available from LAPACK. For research purposes, LAPACK had also been optimized for Intel processors, and some solvers would work in parallel on multi-core systems.

J. Etechells (ESA/ESTEC) asked for clarification about the slide that had shown the divergence of the two solutions. The slide showed a difference between the ODE and QA solver solutions. He was curious to know whether both solutions diverged, or whether it was only one. M. Altenburg replied that ODE15s was the solver that gave the problems.

1.11 Herschel experience on modelling and verification of active heater control

S. de Palo (Thales Alenia Space) presented a brief overview of the thermal control of some of the key systems on the Herschel service module. He went on to describe the challenges involved in verifying the correct functioning of the heater controllers especially in light of the low sample rates available during testing. (See [appendix K](#))

J. Persson (ESA/ESTEC) said that the presentation had shown that they had verified the stability of the temperature control, but asked about the stability of the algorithm that had been developed to verify the test data. S. de Palo explained that when working with the transfer function, it was necessary to set up a control loop. In the MATLAB toolbox the user could set various parameters, such as the Nyquist frequency. In this case, the stability under discussion was not quite the same as that of control theory, and could be described more like a limitation of the temperature variation. From a strictly control theory standpoint, “stability” was not the correct word to describe it.

J. Etechells (ESA/ESTEC) was interested in the Pulse Width Modulation slide, and asked how they had decided on the PWM frequency. S. de Palo replied that all of the timings had already been fixed in the design before the verification stage had been reached. C. Damasio (ESA/ESTEC) confirmed that the time values were all due to limitations of the hardware, and that the control functions had been implemented too late for the findings to be fed back in to influence the design. HP. de Koning (ESA/ESTEC) asked how the 64 second sample time had been discovered so late in the process. S. de Palo said that he did not know the history: he had simply worked with the thermal control team and had not been involved in providing the original requirements for the testing. He admitted that it had been a big surprise. For similar work on Columbus, the thermal model and the hardware had both had a time step of one second so that they could see what was going on. He believed that the problem in this case lay somewhere in the interface to the controller.

1.12 Thermal model and analysis of the BELA transmitter Stavroudis baffle in Mercury orbit

S. Del Tognò (DLR) described the extreme thermal environment anticipated for BepiColombo in its orbit around Mercury, and how this influenced the design of the BepiColombo Laser Altimeter (BELA). He explained how to incorporate temperature dependent thermo-optical properties into the ESATAN-TMS models of the spacecraft, both the GMM and the TMM. (See [appendix L](#))

P. Poinas (ESA/ESTEC) asked when or why they had decided to move to temperature dependent properties. Was it when the first analysis gave the wrong results? S. Del Torno explained that the decision to investigate using temperature dependent properties had been based on the spectrum expected at each orbit position. P. Poinas said that he understood the differences in the spectrum, and asked whether there had been any comparisons with the different optical properties. S. Del Torno said that they had made a comparison later, using fixed values for the optical properties of the baffle, but only for steady state. The transient analysis had given problems, with an error of 10K, which was clearly not desirable.

Day 2

Wednesday 7th October 2009

2.1 Thermal design for an asteroidal lander

R. Nadalini (Active Space Technologies) presented the challenges involved in modelling the thermal environment for a lander on a small asteroid using a generic method that had been inspired by a presentation on EXOMARS at the previous year's workshop. He described how to calculate the solar flux at different latitudes on the asteroid, and the infra-red fluxes based on the local soil temperature profile. (See [appendix M](#))

H. Isik (Turkish Aerospace Industries) asked about the colours shown on the lander model. He had understood that the lower part had a gold coating, but what about the top? R. Nadalini said that the top surface was white because it needed to have a low solar absorptivity and high infra-red emissivity. H. Isik asked why they had not used MLI. R. Nadalini said it all came down to mass. The first approach was to try to use coatings because they were lighter and cheaper. There was a big push to reduce mass, and therefore cost. In the case that they could not achieve the required results using coatings, then they would look at using MLI.

M. Gorlani (Blue Engineering) asked about the next step: which method would be used to cope with differences in slopes, and the orientation of the lander on the surface? R. Nadalini said that the model allowed either to incline the whole surface, or the lander on the surface.

M. Gorlani was interested to know which method had been used to choose the design cases. Did they have some criteria to choose the five worst cases, or was a particular parameter important? R. Nadalini said that the first step was to try to see how important the orientation was. He wanted to have a symmetric design to avoid having to consider too much variation based on which side of the lander was facing the sun or in shadow. The scientists needed to provide information on which kinds of slopes were expected, so that the thermal engineers could do a test run. If the effect was important, they would then try to parameterize the model to take the slope into account. The problem was that any change to orientation or slope affected the radiative model, and so the changes had to be made in the geometry file, and then cascaded through the rest of the analysis. If the parameters affected only the thermal solution, they would be easier to handle. As a workaround, it had been necessary to pre-calculate arrays of fluxes and then select the appropriate array. R. Nadalini said that as far as he was aware, the customer was probably only interested in the worst case analysis and margins, and did not need all possible variations.

M. Gorlani commented that an asteroid had no atmosphere, so that limited any atmospheric effect that would be important for some planetary landers, and therefore calculating the effect of slopes was more important. He said that Blue had performed lots of parametric runs using ESARAD and therefore had experience managing large numbers of analysis cases like the ones shown.

J. Etchells (ESA/ESTEC) asked whether there had been any need to consider the effects of dust on the sky temperature. R. Nadalini replied that this was not necessary for the asteroid environment but would be for a planet such as Mars. He understood that the EXOMARS people had built up a database and extracted the effect on the incident flux, etc. They were then able to damp the solar flux by using a factor relating to the optical depth of the atmosphere. However, for the asteroid case, the effect of any dust was important at and in the surface, and not on the sky temperatures.

2.2 TCDT — Distribution and maintenance

A. Tosetto (Blue Engineering) presented a brief history of the Thermal Concept Design Tool project and its availability to the European space thermal community. He described various improvements that had been made since the previous workshop, based on feedback from users. He demonstrated several of these, such as the improved bounding box and axis display for shells, attitude visualisation, parameterized geometrical models, and improved synchronization of changes between geometrical and thermal models. (See [appendix N](#))

D. Gabarain (ESA/ESTEC) asked whether it was possible to define a radiative case involving an elliptical planetary orbit. A. Tosetto said that the orbit was generally elliptical, so all the user needed to do was to define different major and minor axes.

A. Uygur (Turkish Aerospace Industries) commented on a slide that said that Excel 2007 would be supported in the future. He wanted to know what was supported at the moment. A. Tosetto said that there was already one user who worked with Excel 2007, and that they had not received any problem reports. However, they had not yet run any formal verification tests against Excel 2007.

2.3 A thermal/structural mapping tool for thermo-elastic distortion analysis

D. Wild (Astrium UK) presented details of a process based on simple text files for mapping temperature data from a thermal geometrical model onto a mechanical finite element model. The process used `TASverter` to convert from `ESARAD` to `THERMICA` in order to output the node centres using the UNF format, and a C++ program to perform some simple geometrical mathematics to map temperatures between the models. (See [appendix O](#))

R. Nadalini (Active Space Technologies) said that the presentation had included some nice ideas, and wondered how the process dealt with edge effects, such as the edge of a panel, or junctions, or external edges. D. Wild answered that the software was able to recognise the node on the edge of a panel, and then looked backwards towards the centre. For junctions, the user needed to group nodes together in order to avoid “look-across”. The software would then only map within the groups that had been defined. R. Nadalini supposed that the software calculated based on the 8 regions defined for each node, and beyond those regions the distance to the node would be taken into account. D. Wild confirmed this, but said that the software only looked at the other nodes defined within a group.

M. Bernard (Astrium) had understood that the mechanical nodes on the edge of the panel could look at other nodes in the 8 regions, and that if one panel node was next to a region that was not empty then the mechanical node would have the same temperature. D. Wild said that the user had to manually manage certain edge cases. It was usually a problem of the geometrical model, and it was hard to anticipate when such problems would occur, but it was relatively easy to go back to redefine the groups.

M. Bernard felt that it was an interesting approach to use the centres of the thermal meshes, but said that people were used to thinking in terms of an iso-thermal mesh where all points on a node had the same temperature. For some parts of the model this would have no effect on the end result, but for huge nodes with huge meshes, it could give a great difference between the meshes. T. Soriano (EADS Astrium) remarked that this would then give the node temperature at the point at the centre of the shape. D. Wild said that the coordinates in the universal neutral file represented the centres of the shells. It was the shells that they looked at, so they used the centroids of the shells. For each shell the file also contained some other numbers such as the temperature. T. Soriano warned that the thermal node temperature was the average temperature of the surface, so there could be higher temperatures within the shape. There could therefore be significant differences in actual temperature gradients across big shapes and small shapes with the same average thermal node temperature. Using the node centres could therefore have a large effect on the results. D. Wild agreed, but said that this was really a problem with the thermal mesh, and that such effects were usually easy to see when visualising the results afterwards. The user needed to consider this possibility during the modelling. The developers were aware of the problem and would need to keep an eye on it in the future.

2.4 Updates to the SINAS tool for mapping of lumped parameter temperatures onto a structural FE models

J. Etchells (ESA/ESTEC) presented the work of Simon Martin, a stagiaire who had just returned to Cambridge University. The work during the stage had been to re-implement large parts of the SINAS tool, already presented at previous workshops, in order to simplify the work flow, to develop a replacement for the NASTRAN DMAP functionality for manipulating gradient areas, and to refactor many of the old array constructs that had been inherited from FORTRAN to use modern software idioms such as Python dictionaries. (See [appendix P](#))

A. Tralli (BuNova Development) said that this was a very interesting presentation on an interesting subject. He asked whether the goal had been to redo NASTRAN for thermo-elastic analysis. J. Etchells said that was not the case. They were still using NASTRAN for the structural analysis, but what they had done was to replace NASTRAN for creating the conduction and constraint matrices. The difference between what they had done and most mapping approaches which use the grid positions, was to use the topology of the finite element model to get the mapping. He said he should have included a slide from Simon Appel's presentation on SINAS at the 2006 workshop¹, which showed the results on a non-contiguous mesh. He said that in that example where the two nodes were well insulated from each other, the traditional approach would give strange gradient effects in the finite element model over the insulated boundary. Taking the topology into account as well gave another set of temperature gradients. A. Tralli agreed, especially for the higher order elements.

A. Tralli asked about the use of the Lagrange multipliers, and whether there had been any strange effects. J. Etchells answered that the Lagrange multipliers were only used to apply constraints and to relate thermal node temperatures to finite element node temperatures because they were using a conjugate gradients solver. A. Tralli commented that the difficulty was to handle a matrix with zero on the main diagonal. J. Etchells agreed that the problem was non-positive definite.

¹ <https://exchange.esa.int/thermal-workshop/attachments/workshop2006/appendix/SAppel.pdf>

2.5 ESATAP 2.0.0 — Status and evolution of developments dedicated to thermal end users

H. Rooijackers (ESA/ESTEC) began by giving a brief summary of the goals of the ESATAP project and the history so far. F. Brunetti (DOREA) then continued by outlining the limitations of the early versions, both in performance and memory usage, and that the user interface had been geared towards expert software developers rather than thermal engineering users. He gave a video demonstration of the new task wizard that had been designed to simplify use by thermal engineers. A. Fagot (DOREA) described various improvements to the underlying architecture, mainly to do with user input validation and error checking. They had worked closely with Dutch Space to develop a limits reporting facility which could handle the comparison of results from multiple analysis runs. (See [appendix Q](#))

There were no questions.

2.6 Final validation phases of the IITAS project for Industrial Implementation of STEP-TAS

HP. de Koning (ESA/ESTEC) described current work by the European thermal tool developers to integrate a STEP-TAS import/export facility in their tools using underlying software tools and libraries from ESA, CSTB and the University of Manchester. CSTB had implemented a framework for the automated validation of more than one hundred test cases drawn from the `TASverter` test suite involving import and export of geometrical models in STEP-TAS format into and out of `CIGAL2`, `ESARAD` and `THERMICA`. The validation used `BagheraView` to generate ten standard views of each model, with a pixel-by-pixel comparison of the resulting images. Similar import/export facilities were planned for `TMG` and `Thermal Desktop` in the future. (See [appendix R](#))

S. de Palo (Thales Alenia Space) asked whether the `TMG` mentioned meant the classic version or the new `NX`. HP. de Koning answered that the interface was planned for both versions.

S. de Palo asked how boolean operations would be handled in the conversion of the geometry. HP. de Koning answered that cutting operations would be handled in a similar way to that used by `TASverter`. Cutting operations in `ESARAD` could be exported to boolean operations in STEP-TAS and imported back into `ESARAD`. The result of importing such a STEP-TAS model with boolean operations into another tool depended on how the model was interpreted and the capabilities of the tool. `THERMICA v4` has some support for cutting operations, but not for all shapes. Some shapes could be handled directly, but more complicated operations would generate a warning and require some manual clean-up. Where possible, the boolean operations should convert automatically, leaving the rest for manual conversion. `CIGAL2` did not handle cutting operations, so importing a model with boolean operations would generate a warning and the user would need to do something manually to adapt that part of the model.

2.7 Mathematical models for the Columbus engineering support team

S. de Palo (Thales Alenia Space) gave an overview of the various thermal mathematical models developed for the analysis of the Columbus air and water loops during the CDR and FAR phases, and their continued use to help monitor the Columbus thermal environment in flight. He

described the analysis of telemetry data showing unforeseen behaviour in the cabin air loop, and the investigation into the cause. (See [appendix S](#))

HP. de Koning (ESA/ESTEC) noted that there had been some talk of extending the ISS mission to 2018 or even 2020, and asked whether there was a need to start planning for related analysis. S. de Palo said that he had presented the current analysis standpoint and that someone else [a non-analyst] must have been talking about future plans. He had seen presentations about the ATV, and has been curious to know whether similar CDR models had been used for brainstorming on-orbit situations.

HP. de Koning asked about the format of the received telemetry data. S. de Palo answered that the data was received in Excel and ASCII files.

J. Persson (ESA/ESTEC) commented that when the model had been correlated in phase C/D, they had used idealized conditions. He wondered whether there had been any adjustments for the flight configuration. S. de Palo said that he was mainly concerned with the ATCS. He had correlated the pump assembly results against the telemetry and had modified the model to fit the flight data, but this had not been done for the CDR. The CDR sizing had been performed for the entire system. The model now needed some parameterization to handle information available from the telemetry for configuring the pump package, etc. Fixed ICD values had been used for the heat exchanger limits in the CDR analysis, but these did not reflect the dynamic values encountered under real conditions on the space station. He thought that there was a need for more detailed modelling of the heat exchangers in order to understand some of the transients seen in the telemetry.

2.8 On orbit performance of the EuTEF thermal control system — 1 Year on board the ISS

A. Franzoso (Carlo Gavazzi Space) presented an overview of EuTEF, a platform mounted on the outside of the Columbus model that housed various instruments with passive thermal control systems. He described the investigation of unexpected temperatures observed in the telemetry data and how these were tracked back to certain mission events requiring particular orientations of the space station. He also described the use of `SINDA` and `TOPIC` to make a simple six-node model for rapid analysis in order to avoid the 12-hour analysis runs required for the complete model. (See [appendix T](#))

M. Gorlani (Blue Engineering) had a remark about using `TOPIC`. He said that `TOPIC` was included with the Thermal Concept Design Tool, and that the `TCDT` could be used as a pre-processor to provide input for `TOPIC`. A. Franzoso stressed that the use of `TOPIC` was not a choice based on such factors such as the reliability of the model, but simply because they wanted to have the lowest level of complexity for a new engineer who would only be working on the project for a couple of weeks. `TOPIC` provided the simplest interface of all of the tools. They had nothing against using the `TCDT`. M. Gorlani said that the `TCDT` could launch `TOPIC` and then provide the results in Excel.

D. Battaglia (Thales Alenia Space) had noted that in the explanation about the reduction of the model they had tried to remove the CEPA. He wondered how they had then been able to use the temperature as a boundary condition. A. Franzoso explained that they had used the flight data as the base board for the correlation. The CEPA was the common adaptor for all of the EuTEF payloads. They had not used the CEPA as a free condition, but the results were good, even for those elements not coupled by the CEPA.

A. Franzoso commented that they would need lots of stagiaires to investigate all of the interesting flight data that had come from EuTEF.

2.9 Workshop Close

H. Rooijackers (ESA/ESTEC) thanked all of the presenters and participants, reminded them of the deadline for the ICES submissions, and looked forward to seeing everyone again at the next workshop.

Appendix A

Welcome and introduction

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Appendix B

Progress of the CIGAL2 distribution project

Thierry Basset Jean-Paul Dudon
(Thales Alenia Space, France)

François Brunetti
(DOREA, France)

Abstract

To increase the reactivity and performance of thermal analysis, Thales Alenia Space Cannes has decided to integrate step by step its thermal software CORATHERM in the graphical pre and post-processing tool CIGAL2. As it was presented at 2008 ECLS workshop, the objective is to take profit of the powerful, complete and user friendly framework offered by CIGAL2 to extend it to end-to-end thermal analysis process including also computation management.

This year we intend to provide to European thermal users a new release of this integrated tool which will include a full integrated 3D conductive chain, a thermal model reduction tool (Thales Alenia Space Torino & Toulouse) and an orbitography module. Besides this the CIGAL2 new generation application combines a powerful modelling and meshing tool with the main CORATHERM modules to perform thermal analysis on a future satellite or payload.

This paper presents also the improvement brought to Coratherm architecture in order to make it more outstanding and to increase its performances and reactivity. Recently CIGAL2 has been chosen to be the CAD modelling tool for draft designing of satellite thermal control during invitation to tender phases in Thales Alenia Space Cannes.

Finally, this tool will be also available soon for other purpose than thermal such as ESD analysis, CIGAL2 integrating SPARCS simulation complete process and for electronics thermal control design.

Appendix C

Heat shield thermal sensitivity analysis

Matteo Gorlani
(Blue Engineering, Italy)

Valter Perotto
(Thales Alenia Space, Italy)

Abstract

The presentation will provide the results of the sensitivity analysis performed for the thermal model of Solar Orbiter Thermal Heat Shield. The sensitivity analysis applied to the geometrical mathematical model and the thermal mathematical model of the Solar Orbiter Thermal Heat Shield, has been performed with the stochastic approach based on the Monte Carlo Simulation method. The whole procedure will be described.

Appendix D

TMRT

A thermal model reduction tool

Mathieu Bernard
(EADS Astrium, France)

Thierry Basset
(Thales Alenia Space, France)

Sandrine Leroy François Brunetti
(DOREA, France)

James Etchells
(ESA/ESTEC, The Netherlands)

Abstract

TMRT is a software performing thermal model reductions, based on equivalent conductance matrices. It gathers the experience and knowhow of both THALES ALENIA SPACE and ASTRIUM in this domain. The presentation will first introduce the theory of the reduction method. Then, a demonstration will be made and used to show the advantages of the TMRT reduction method.

Appendix E

GENETIK

Genetic algorithm for the sizing cases research

Hélène Pasquier Stéphane Clouet
(CNES, France)

Abstract

GENETIK is a CNES internal tool which use genetic algorithm for sizing cases research. A first development phase has been started in 2005, with a validation on simple cases.

In 2009, a second development and validation phase has led to an optimized tool in term of results and methodology.

The objectives of the presentation are the following:

- Describe the principles of genetic algorithms,
- Focus on optimization in GENETIK in term of algorithm operators and methodology,
- Present validation cases and results.

Appendix F

SYSTEMA

Marc Baucher
(EADS Astrium, France)

Abstract

V4 modularity

Previously, on v3 releases, creating the input data of a simulation was based on a sequential process. Now the v4, in addition to extended modeling capabilities, brings a new way of building models and missions. The modeling process in v4 is completely based on a modular and dynamic framework that makes switch possible from all input data. Moreover, any modification is dynamically applied to all other related elements.

This first part reminds the v4 concepts and compares v3 and v4 processes.

Parametric analysis & Batch process

In version 4.3.3, the concept of parameters allows to define parametric models and missions. It is also now possible to perform complete batch process using parametric inputs.

Interfaces

SYSTEMA / THERMICA has now a new import/export integrated option with the STEP-TAS format. Moreover, a new converter translates the SYSTEMA native output format (HDF5/SDS) to STEP-NRF. This will also allow the integration of ESATAP in post-processing.

Appendix G

THERMICA – THERMISOL

Timothée Soriano
(EADS Astrium, France)

Abstract

Process Control

Presentation of the new functionalities & outputs dedicated to control the convergence of the simulations.

- New summary tables in log files for Ray-Tracing algorithms
- New accuracy loops in the Radiation & Solar Flux modules
- Extended data in the THERMISOL process control file
- New error definitions in THERMISOL

THERMISOL to ESATAN converter

THERMISOL is based on the ESATAN language and more than 95% of the commonly used syntax is supported by both software. THERMISOL now offers additional advanced functionalities and also more users friendly syntax (free format, real format automatic adaptation, easy Mortran data access ...). To ensure the compatibility, a converter translates a THERMISOL input file and re-formats it in order to be 100% compliant with both software.

Latest Validations & Performances Tests

The v4 is now completely mature to be integrated into production processes.
This is a short presentation of process integrations and results based on industrial cases.

Appendix H

ESATAN Thermal Modelling Suite Product developments

Henri Brouquet
(ITP-UK, United Kingdom)

Abstract

Overview of new features introduced in the latest versions of ESATAN-TMS.

Appendix I

ESATAN Thermal Modelling Suite Demonstration

Henri Brouquet
(ITP-UK, United Kingdom)

Abstract

Demonstration of the latest version of ESATAN-TMS.

Appendix J

Methods for solving linearized networks in satellite thermal analysis

Martin Altenburg Johannes Burkhardt
(EADS Astrium, Germany)

Abstract

The presentation discusses a further development step of the Astrium in-house S/W tool TransFAST. This tool was originally developed in order to establish methods for calculation of transfer functions in the frequency domain, as was required for thermal analysis of the LISA missions. The mandatory first step of such type of analysis is the transformation of the classical thermal network to a standard linear control system by linearization of the radiative terms at a certain steady-state. As an extension of the existing tool, this linear control system shall be solved in the standard time domain.

Application of this type of analysis becomes important for all missions, where extremely demanding requirements on geometrical and thus thermo-elastic stability are involved. In such cases the deviations from a certain steady-state are small enough for performing thermal analysis on linearized systems. The major aim of such methods is to perform analyses with significantly less effort compared to the classical approach, but promising to deliver reasonable and even more accurate results.

Two different approaches for solving the linearized thermal network in the time domain are presented, the well-known ordinary differential equation (ODE) methods, and a quasi-analytical method, which splits the differential equations in a homogenous and an in-homogenous part. The major advantage of analytic solutions would be that no transient calculation for the whole time period is necessary. This is particularly suitable for problems where only a small number of specified time points are of interest. Also these time points can be selected w/o any limitation w.r.t. exactness of the solution, because the calculation requires only the analysis of a function, instead of solving an algorithm which gradually time step by time step creates the solution. This implies that a (final) steady-state solution caused by a certain disturbance can be directly calculated without having potential numerical problems as for a transient calculation. Results obtained by these two approaches are compared vice versa and with results calculated by the standard thermal analysis S/W.

Appendix K

Herschel experience on modelling and verification of active heater control

Savino De Palo Marco Compassi
(ThalesAlenia Space, Italy)

Claudio Damasio
(ESA/ESTEC, The Netherlands)

Abstract

Herschel satellite was launched on May 14th, 2009 and is currently orbiting 1.5 million kilometres away from the earth on the second Lagrange point (L2) of the Sun-Earth system.

Main objective of the active thermal control system is the thermal stability of two HIFI instrument units ($3 \cdot 10^{-4} \text{ }^\circ\text{C/s}$) and of the Star Tracker mounting plate ($2.5 \cdot 10^{-4} \text{ }^\circ\text{C/s}$). After a brief introduction of the satellite, the presentation provides a general view on the lesson learnt from the thermal vacuum and thermal balance (TVTB) test performed in the ESA-ESTEC Large Space Simulator (LSS), control system design, thermal modelling and the current status of the ESA telescope.

Appendix L

Thermal model and analysis of the BELA transmitter Stavroudis baffle in Mercury orbit

Simone Del Togno Gabriele Messina
(DLR, Germany)

Abstract

In the frame of the ESA BepiColombo mission to the planet Mercury the German Aerospace Center (DLR), in cooperation with the University of Bern, is designing the first European laser altimeter for planetary exploration (BELA).

While orbiting Mercury the solar flux reaches 14 kW and strikes on the instrument at angles of ≥ 38 deg from the instrument line of sight. The planet surface reaches 700 K while the view factor with the instrument aperture is high due to the low orbit altitude.

Under these conditions a major challenge is the design of the instrument baffles, which shall avoid direct sunlight to reach the optics, minimize the heat load to the instrument and the S/C cavity and reduce stray light.

We describe the thermal model of the transmitter baffle, focusing on advanced features like the approximation of ellipsoids and hyperboloids in the geometrical mathematical model, its optimization with respect to computational time and baffle efficiency, the dynamic implementation of wavelength dependant thermo- optical properties for the calculation of both absorbed planetary fluxes – as function of Mercury surface temperature – and radiative conductances (GR).

The worst cases selection in the scenario of the whole Mercury orbit about the sun is also presented followed by a detailed overview of the analysis results.

Appendix M

Thermal design for an asteroidal lander

Riccardo Nadalini
(Active Space Technologies, Germany)

Abstract

After JAXA Hayabusa and NASA NEAR missions, several missions toward Near Earth Objects (NEO) are currently under study. One of the ongoing studies, part of the ESA cosmic vision 2015-2025 program, regards the ESA-JAXA cooperative Marco Polo mission, which aims at sampling a primitive NEO (D- or C-type).

Different landers are simultaneously under study by different teams. One of them is an Extra Small (XS), 10-kg class lander, studied by DLR in its concurrent engineering facility, study in which Active Space Technologies provided the thermal analysis and design that is presented here. Due to the limited resources available, the thermal control system must be entirely passive (no heaters).

Thermal requirements of the various systems are not extreme but they have to be maintained by insulating against a very harsh thermal environment (with a surface thermal excursion of 170°C in 2 hours) while, at the same time, dumping the dissipated heat (ca.12W) to the outside.

The analysis process of this Marco Polo lander follows a pattern that is exemplary for any object (lander or instrument) placed on the surface of an airless body in the solar system. First, the thermal characteristics of the body surface need to be established for different times in the available landing windows, then the worst cases are selected and the illumination of the object surfaces for them is calculated.

Once the environment (fluxes, soil, and surface temperature) is calculated, the thermal model of the lander can be combined with the model of the soil connected to the lander (immediately below) as well as with the appropriate boundaries (the surface of the asteroid in the surroundings) and the thermal design of the lander, in terms of connection and coatings can be performed.

In the case of the XS lander, the preliminary design is based on a good conductive and radiative insulation from the soil and in a mostly radiative dumping of the internal heat to the deep space.

Appendix N

TCDT

Distribution and maintenance

Andrea Tosetto Matteo Gorlani
(Blue Engineering, Italy)

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Abstract

The activities of the 3rd M&D year will be described by focusing on new developments and installation adaptations for ESTEC CDF. A demonstration of the beta TCDT ver.1.3.1 with the new GUI and the 3DViewer with the satellite in orbit will be given. A presentation of a stochastic/parametric analysis by means of the parametric engine of the TCDT will be given in order to demonstrate the usefulness of the parametric approach introduced with version 1.3.0

Appendix O

A thermal/structural mapping tool for thermo-elastic distortion
analysis

Daniel Wild
(EADS Astrium, United Kingdom)

Abstract

As thermal and structural models become larger and more complex, the labour involved in mapping temperatures from thermal to structural models has naturally increased. This presentation describes a method that has been developed to aid the process of temperature mapping to structure models for thermo-elastic distortion. The process is centred on a mapping tool that allows the semi-automatic mapping of temperature data to structure models, independent of analysis software, thus reducing the hours required for this task. The presentation will provide an overview of the key aspects of the process, issues that may arise, their solution and potential future developments.

Appendix P

Updates to the SINAS tool for mapping of lumped parameter
temperatures onto a structural FE models

Simon Martin James Etchells Simon Appel
(ESA/ESTEC, The Netherlands)

Abstract

SINAS is a software tool that enables lumped parameter temperatures (e.g. ESATAN results) to be mapped onto a structural FE model for thermo-elastic analysis. This tool was originally developed under a series of ESA contracts with Dutch Space (previously Fokker Space) but is now maintained by ESA D/TEC-MTV (Thermal Analysis and Verification Section).

This presentation will describe the work that has been done to update SINAS and present current status of the tool. In particular the following topics will be covered:

- Re-engineering of several old SINAS modules into a single Python module
- Development of FE algorithms to allow the SINAS process to be independent of NASTRAN
- Application of the new SINAS module to an industrial model

Appendix Q

ESATAP 2.0.0

Status and evolution of developments dedicated to thermal end users

Alain Fagot François Brunetti
(DOREA, France)

Harrie Rooijackers Hans Peter de Koning
(ESA/ESTEC, The Netherlands)

Abstract

ESATAP is a post processing tool for large sets of thermal result data in STEP-TAS/STEP-NRF datasets. ESATAP 1.0.2 was presented at the last workshop.

Since last year feedback and requests of users have been taken into account to make the new version more robust and user friendly.

ESATAP 2.0.0 will be released end of 2009 and will provide:

- A Wizard mode to guide the user step by step while processing a task.
- New plot component allowing faster and easier analysis of min-max temperatures on single or multiple cases.
- A check mode simulating and validating processes (tasks) before launching the real execution.
- Enhanced performance for handling large datasets (enhanced loading and merging capabilities).

Appendix R

Final validation phases of the IITAS project for Industrial Implementation of STEP-TAS

Eric Lebègue
(CSTB, France)

Hans Peter de Koning
(ESA/ESTEC, The Netherlands)

Abstract

This presentation presents the status of the industrial STEP-TAS converters integrated within ESARAD, THERMICA and CIGAL2. It presents the final phases of the IITAS project with particular focus on the validation performed by Astrium, ITP, Thales Alenia Space, Dorea, CSTB and ESA and based on automatic and manual validation.

Appendix S

Mathematical models for the Columbus engineering support team

Savino De Palo Gaetana Bufano Albina Quaranta
(ThalesAlenia Space, Italy)

Marco Bruno
(Sofiter System Engineering, Italy)

Abstract

Columbus module started its operations on early 2008 as European element of the ISS. Mathematical models originally developed for CDR/FAR phases and fitted to current flight configuration play a key role for the engineers supporting the on-orbit operations.

This presentation provides an overview of the Thermal-Hydraulic Mathematical Models (THMM) running in TAS-I Torino by thermal control team, focusing then on the water loop Active Thermal Control System (ATCS) element, by comparing flight telemetries with models outcome for some relevant cases. Conclusions summarize this first year of experience covering also s/w needs and expectation for next future.

Appendix T

On orbit performance of the EuTEF thermal control system 1 Year on board the ISS

Alberto Franzoso

Marco Molina

Paolo Ruzza

F. Tominetti

M. Grilli

(Carlo Gavazzi Space, Italy)

Abstract

EuTEF is an ESA platform for technological research, designed and built by Carlo Gavazzi Space. It was launched onboard the Space Shuttle on February 2008 with 10 experiments to be exposed to Space Environment for 15 months. It was installed as an attached payload of the Columbus module by astronaut EVA.

EuTEF is experiencing the typical ISS outer environment, dominated by LEO sun-eclipse phases on a medium inclination orbit (52°), with the additional effect of the International Space Station moving appendages. Thermal modelling with SINDA/TRASYS code has been used for sizing of the payload: the NASA-provided ISS model (in SINDA) has been used for flight predictions, which are compared with flight data.

Within the 1 year mission, the seasonal variations in the thermal environment of EuTEF are identified, and signs of degradation of the thermo-optical properties of the thermal coatings, such as silvered Teflon, have been investigated from telemetry data.

Moreover, it is calculated how much the ISS elements dominate the environment for payloads attached outside Columbus module, compared to free-flying satellites in a similar orbit. Simple thermal tools such as ARTIFIS and TOPIC have been used to derive an equivalent effective thermal environment of the outer ISS, with solutions implemented in MINITAN. These extremely simplified models allow making considerations for preliminary thermal design of future missions on the ISS.

EuTEF returned safely on the Earth in September 2009: thermal requirements about the return are briefly presented as well.

Appendix U

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