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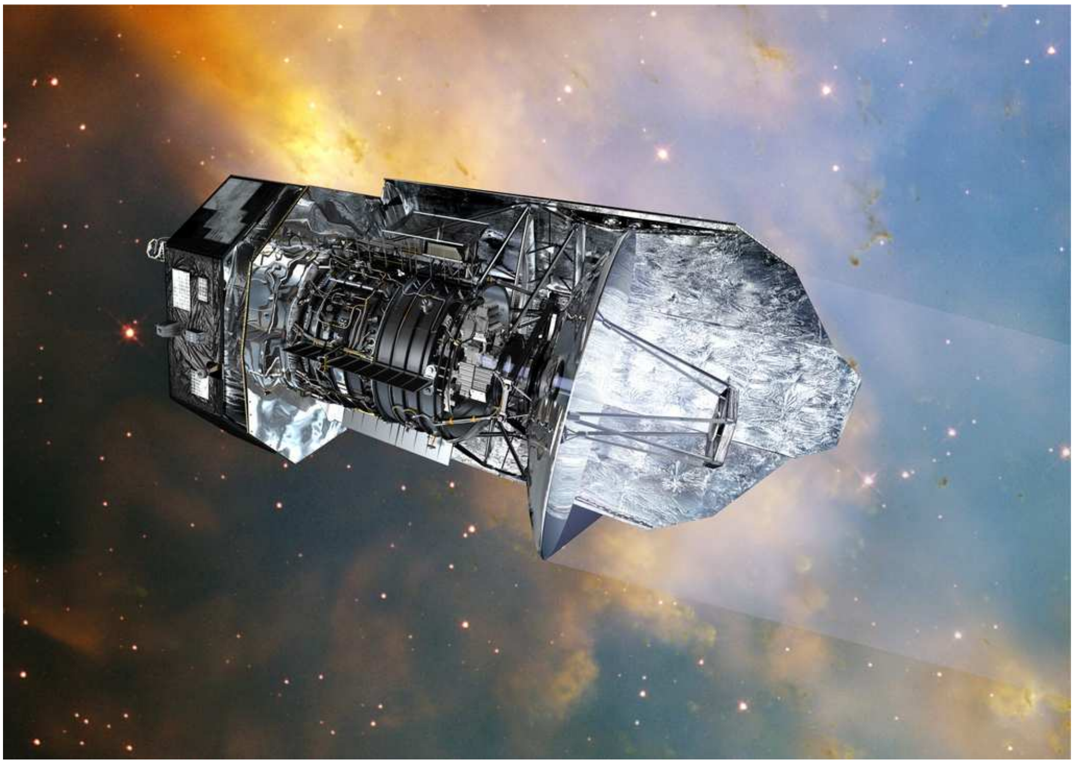

European Space Agency
Agence spatiale européenne

Abstract

This document contains the minutes of the 22nd European Workshop on Thermal and ECLS Software held at ESA/ESTEC, Noordwijk, The Netherlands on 28–29 October 2008. 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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Day 1

Tuesday 28th October 2008

1.1 Welcome and introduction

H. Rooijackers (ESA/ESTEC) welcomed all of the participants to the workshop. He explained the main goals of the workshop were to provide a forum for discussion between the users and the developers, for the developers to present advances in the the tools, and for the presentation of new methodologies. He reminded everyone about the 2008-11-14 deadline for the submission of papers to next year's ICES conference to be held in Savannah, Georgia, USA. (See appendix A)

1.2 Columbus Thermal Control System On-Orbit Performance

J. Persson (ESA/ESTEC) presented details of an analysis of the Columbus thermal control system that he had performed to investigate unexpected power readings in the pre-launch period. He described the results for two different configurations of the water loop on different days and the verification against in-flight data. (See appendix B)

H. Rathjen (Astrium GmbH) had noticed the use of GFs on the slides and asked whether the water loop had been modelled using `FHTS`. J. Persson said that the water loop submodel was an `FHTS` model that had come from industry, and maybe they could also explain the issue about the pump speed. S. de Palo (Thales Alenia Space) confirmed that they had worked on the `FHTS` model. He suspected that the problem was due to the fact that in the model the maximum pressure drop across the heat exchangers was a constant, and that this did not correspond to the real pressure drop seen in flight. He thought that this would explain the differences in the pump speeds.

M. Molina (Carlo Gavazzi Space) had noticed that J. Persson had not included the EUTEF in the model. He said that in the cases when the ISS orbit gave a high beta angle, the EUTEF shadow on Columbus could affect the absorbed flux and therefore the temperatures. For the -XVV orientation with positive beta angle there would be no shadow from the EUTEF and so there would be a lot of sun on the port side. J. Persson said that this could explain the effect locally. The EUTEF was at the 'top' so he could always check if there were differences between the port and aft overhead zones.

M. Molina added that when the shuttle docked with the ISS, there was a complete 180° change around the yaw-axis, and this would be a great opportunity for the model correlation. J. Persson acknowledged that this would provide better confidence in the model, but wondered whether the potential benefits justified the cost of the work, especially when the existing model already provided results that gave a good-enough match with the flight data.

1.3 Experience of High Accuracy Thermal Modelling from the LISA Pathfinder Thermal Noise Analysis

N. Fishwick (Astrium UK) described the stringent thermal stability requirements for LISA Pathfinder. He presented new methods that had been developed to structure the ESATAN model in order to have confidence that numerical variation had been reduced sufficiently to show that the thermal stability requirements had been met. (See appendix C)

E. Overbosch (Dutch Space) asked how they intended to verify such an accurate model. He said it was always possible to make a prediction, but how could they ever know how the hardware would react because they could never test it to this level of accuracy. N. Fishwick admitted that this was a very good question. They could not measure to that accuracy, but they could see whether the instrument worked. O. Pin (ESA/ESTEC) said that this was a case of verification by analysis, although he admitted that a test would be better. S. Price (Astrium UK) commented that there was such a high uncertainty because it wasn't possible to verify by test. E. Overbosch said that there were so many details and wondered how you could ever be convinced that the TMM was of a high enough standard.

M. Molina (Carlo Gavazzi Space) argued that in reality it might be possible to make a more positive statement by considering the linear model behind everything. If it were possible to demonstrate that the linear model gave good results, and could verify the linear model for different inputs, then it would be possible to have confidence. Once it had been demonstrated that the model fitted reality in the linear domain using some step function or wave equation, then you could have more confidence in the results.

M. Molina commented that the name 'PSD' had been inherited from the structural analysis world, and felt it was not appropriate to use it for the thermal analysis. In a previous workshop he had already proposed the terms *Temperature Spectral Density* (kelvin per root hertz) and *Power Spectral Density* (watt per root hertz) to avoid any confusion. N. Fishwick agreed that this was a good idea. M. Molina asked that the function name in ESATAN should be changed to reflect this. H. Brouquet (ALSTOM) replied that it was already called the *Linear Spectral Density* in ESATAN.

P. Poinas (ESA/ESTEC) wanted to return to slide 4. He had noticed that N. Fishwick had said that the solution would converge to the level of the model. What had he meant? That if the dimension was given as 10e-6 that the solution would converge to 10e-6? N. Fishwick said that the solution depended on the number of digits given to the MATLAB routine. If the initial state were given with 6 decimal digits, then the result would vary by 10e-6. P. Poinas commented that this variation was independent of the model size and complexity itself.

O. Pin admitted that the fact that ESATAN executed the solver using double precision was clearly something to look at, but he was interested to know whether the different ways of specifying the initial conditions had an effect on the PSD results. He asked whether they had produced a clear curve showing the results of starting in single precision and then comparing with results obtained with the double precision 'tricks' that had been presented. If the results were the same, he wondered whether there was any advantage in doing all of the work to convert the model to double precision. N. Fishwick said that he did have such a graph, but had not included it in the presentation. The graph showed that there was not much difference between using single and double precision, but they could not have known that in advance. M. Molina commented that it was not the actual number produced that was important, but the variation in the result. O. Pin agreed, but said he would need to see the single-precision graph to see whether it would be really necessary to invest.

H. Brouquet had some comments to make on work that been performed by ALSTOM to investigate the numerical drift in ESATAN following Ulrich Rauscher's presentation at the previous workshop. The first point to note was that the model had only used the RELXCA control constant, and they had shown that using ENBALA as well would give a better solution. The second point was that there was no difference in the PSD results when using single or double precision. However, this issue had become such a source of concern for users that ALSTOM had already decided to convert all of ESATAN to use double precision. The next version of ESATAN would store all model data in the MDB file in double precision. This had been due for announcement in the ESATAN presentation later anyway. The third point was that there was no inherent limit in the number of nodes that could be handled by the SLFRTF routine. However, there was a limit on the size of the model that could be stored in memory on a particular machine. Users were advised that the more performant the machine they had, the more nodes they could handle. C. Kirtley (ALSTOM) explained that the SLFRTF routine used a matrix method, so it did need a lot of memory to handle a large number of nodes.

1.4 New Technology for Modeling and Solving Radiative Heat Transfer using TMG

C. Ruel (MAYA) presented two major developments within TMG. The first was the support for non-grey body radiation analysis using multi-band optical properties. The second was the introduction of parallelization into various parts of the calculation chain to allow simultaneous solution on multiple processors. (See appendix D)

H. Rooijackers (ESA/ESTEC) asked how Maya intended to parallelize the solvers. C. Ruel replied that they would not be introducing new software but would instead be modifying their own solvers to do the parallelization in their own code.

1.5 The ESATAN Thermal Suite

C. Kirtley (ALSTOM) presented a brief history of the different releases of the tools over the past few years and the new features that had appeared with each release, and how this history fitted into ALSTOM's vision for the tools in the future. It had become clearer to ALSTOM that the tools had become more closely coupled over time and that it now made sense to integrate them further. He then introduced the ESATAN-TMS workbench framework that would be available to users at the start of 2009. (See appendix E)

P. Poinas (ESA/ESTEC) said that he was a new user to the current versions of ESARAD and ESATAN. He wanted to know whether the new version would remove the conflicting options for running analyses. It was confusing to be offered options that applied to running within the different mission, radiative and analysis cases as well as running outside the cases. Would the new version clean these options? Would it be backward compatible? C. Kirtley said that the changes would be backward compatible, so it would still be possible to import old models. The menu system in the new version had been significantly cleaned up. He said this would be clearer in the demonstration later.

P. Poinas asked whether ALSTOM were sure that industry were actually using the analysis case and mission definitions, or were they using the functions independently. For example, the user could define mission and analysis cases in a simple way, but there were lots of other options available in the GUI. Were these options used or not? C. Kirtley said that the simple answer was Yes. People were mainly using the radiative case and analysis case method of working. H. Brouquet (ALSTOM) said that people often ended up using some of the low-level functions by mistake, rather than the high-level features of the radiative and analysis cases, and he agreed that it was confusing, especially for new users. He asked for everyone to wait for the demonstrations later.

S. de Palo (Thales Alenia Space) asked whether the CAD interface was included in `ESATAN-TMS`. C. Kirtley said that the `CADconverter` was still a separate tool but that it could be added to the command menu in the GUI. The `CADconverter` was not a standard utility within the workbench at the moment and required a separate licence.

M. Gorlani (Blue Engineering) asked whether it was still possible to import CAD/STEP models into `ESARAD`. H. Brouquet said that in `ESATAN-TMS` the process had not changed at the moment. The user needed to use the `CADconverter` to generate an `ESARAD` geometry file that could be imported. He pointed out that `STEP-TAS` files were different. M. Gorlani asked whether it was possible to do this directly from `ESARAD`. H. Brouquet said that it was not possible to import them directly. The user first needed to convert the STEP AP203 file using the `CADconverter`, but the user could launch the `CADconverter` from the workbench. He said that ALSTOM were looking at ways of merging the tools in the future, but for the moment the `CADconverter` was still a separate program.

1.6 Stability Analysis in the Columbus Active Thermal Control System

T. Klingberg (ESA/ESTEC) presented details of an investigation into the stability of the PID controllers used in the water loop of the Columbus thermal control system. He described a variation on the Nyquist criterion and its use in determining the sensitivity of the controllers to changes in their operating parameters. (See appendix F)

S. de Palo (Thales Alenia Space) wondered about the heat exchanger model. He said that if you relied on the `ESATAN/FHTS` element then there was no way to model the efficiency of the heat exchanger. He wondered whether it had been possible to model this in some other way. He also wondered whether any thought had been given to modelling other types of controller. For a hypothetical Columbus-2 and other future applications it might be possible to have something better than a simple PID controller. T. Klingberg said that it would be interesting to look at applications where it would be necessary to analyze how two controllers could affect each other. It could be that a PID controller was not really good for this application and that it might be better to have a state controller, or a nested [cascade] controller if one had more effect than the other. However the PID controller was the classical industry standard. For the heat exchanger, the `FHTS` model assumed that the exchange was perfect and that the temperature of the ammonia would become the temperature of the water. The equation for the heat exchanger had been given on one of the slides: epsilon was the efficiency of the heat exchanger. T. Klingberg had used the equation that had come from Alenia, but as far as he was aware it was the same one that NASA was using.

J. Etchells (ESA/ESTEC) had noticed that the analysis had required the linearization around the mass flow rate. He asked whether the results from the model were available. When asked what the range of applicability of the linearisation was, T. Klingberg said that the model was valid near a working point, and further from that point provided that the system was near linear. The big potential non-linearity here was the control valve, but the valve never

went beyond 80% non-linear. There were other non-linearities so more research would be needed.
S. de Palo commented on the non-linearity. He said that he had given a presentation at the previous workshop describing the linearization of all working points that the system could have, with lots of configurations. Simply changing five parameters would need lots of changes elsewhere just to see the changes for the heat exchanger. The system described today was much more linear. T. Klingberg admitted that he had to give a lot of credit to TAS-I for their work on nodes two and three, but these used a different linearization. So far he had only looked at simple configurations.

1.7 THERMICA — On-going research and developments

T. Soriano (Astrium Satellites) described some new features that had been developed in `SYSTEMA` and more particularly in `THERMICA` since the previous workshop. He demonstrated boolean geometry and cutting operations and the video playback feature that also showed the kinematics and trajectory cabapilities. He also gave a brief description of the Reduced Conductive Network method for calculating linear conductive couplings. (See appendix G)
HP. de Koning (ESA/ESTEC) asked whether a white paper was available that described the RCN method. T. Soriano said that they had not published it yet, but would do in the future.

1.8 A Software Tool Applying Linear Control Methods to Satellite Thermal Analysis

M. Altenburg (EADS Astrium) presented the development of `TransFAST`, a software tool to help transfer results from a classical thermal network to a standard linear control system and to solve this system in the frequency domain. (See appendix H)

S. de Palo (Thales Alenia Space) asked what software had been used for the solver. Was it `MATLAB`? He also wanted to know more about the format used for the `ESATAN` import.
M. Altenburg said that `MATLAB` had been used for everything. He said that they had used the option with `ESATAN`-10.2 to output to CSV format from the steady state. This was easy to read in `MATLAB`.

M. Molina (Carlo Gavazzi Space) asked whether it was possible to combine different types of disturbances, and if so, how did they ensure that they were dimensionally consistent.
M. Altenburg said that boundary nodes only were used for subsystems and that single sources were used for power as a first phase. The transfer function included both gain and phase shift information, but it was not easy to scale both at the same time, and this allowed them to use a state space model where the user could define two or three inputs and summarize the effect. In the other approach it was only possible to sum the inputs without considering the phase.

M. Molina said that in LISA Pathfinder, there were some disturbances that were internal and some that were external. There were temperature fluctuations in the skin, and power fluctuations in the diodes. Would it be possible to handle both of these in `TransFAST`?
M. Altenburg said that the user needed to take separate sources and create a single input vector: `TransFAST` did not handle 'real' inputs.

M. Molina commented that everyone had seen that there were different requirements at the satellite, payload, and instrument levels and wondered how the different groups superimposed the margins. Was everyone using the same approach? Was everyone superimposing the margins, or using the same calculations?
S. de Palo asked about the maximum number

of nodes that TransFAST could handle. M. Altenburg said that there was no limit for the DIT [Direct Inversion of the Transformed] matrix but there was a limit of 2000 nodes for the CEF [Conditioned Evaluation of the Frequency response] matrix. S. de Palo then asked whether the tool was used on a 64-bit machine. M. Altenburg said that the tool worked on a normal PC. He said that the difference between the two approaches was that for one they conditioned the vectors before the calculations and this made it fast to calculate the frequency gain between nodes. For the other approach they used the gain between all nodes and then did the calculation.

M. Molina asked how the disturbances were defined. M. Altenburg said that they used a vector containing a series of zero or one unit steps. The next version would have the possibility to have a real value between zero and one and then calculate the direct power dissipation.

M. Molina asked whether TransFAST would be available to subcontractors. M. Altenburg said that he did not know, he had only been involved on the programming side.

1.9 ALSTOM Product Developments

H. Brouquet (ALSTOM) presented the different aspects of the new ESATAN-TMS workbench and highlighted the new simpler and integrated user interface, the possibility to run non-orbit cases for the analysis of instruments in test chambers, the ability to define and visualize time- and temperature-dependent properties, and the performance and scalability improvements that would allow larger geometrical models such as those imported from CAD. He gave a demonstration of ESATAN-TMS and also showed how existing PcESATAN users could easily transfer their models into the new workbench. (See appendix I)

S. de Palo (Thales Alenia Space) asked how the licences would work for the different menu options and how they applied to batch processing on Linux clusters. H. Brouquet said that if the tools already worked on the same platform then they would also work within the workbench on that platform. S. de Palo asked how it would work if he only wanted to use ESATAN. H. Brouquet said that as soon as the model was opened in the GUI it would take whichever licence was appropriate. When running in batch mode there would be no need to take an ESATAN-TMS-GUI licence. M. Gorlani (Blue Engineering) asked whether this meant that each user now needed three licences. H. Brouquet answered that the user would require one licence for the GUI, one for the ESARAD part if an ESARAD model was open, and one for the ESATAN part if an ESATAN model was open, but this didn't really change how the user would work. All that would happen was that the new licence file would contain an entry for an ESATAN-TMS-SPACE licence instead of an ESARAD_PRO licence. S. de Palo asked what would happen if you opened as many GUIs as you had licences. H. Brouquet said that it would work the same way as it did now. Using ESATAN required an ESATAN licence, and using ESATAN from within ESARAD required both an ESATAN and an ESARAD licence. He said that the new licence system meant that a user who did not work in a space environment did not need to have a licence to run the mission calculations. The new licences had different levels. The ESATAN user currently had a combined licence that allowed use of both the GUI and ESATAN, and current users would automatically receive the separate GUI licence as well. S. de Palo said that they were running from Linux, and therefore did not use PcESATAN, and did not want to occupy licences just because the GUI was open on the screen. H. Brouquet assured him that the ESATAN user would get a GUI licence on top of what they had now.

G. Tonellotto (ESA/ESTEC) asked whether the new variable property feature was only available as a function of temperature. H. Brouquet said

that the new feature offered time dependent boundary conditions *and* temperature dependent material properties.
M. Bernard (Astrium) asked whether the new system allowed the user to interface in-house subroutine libraries that had already been developed for `ESATAN`. H. Brouquet showed that the Analysis Case dialog provided an area where the user could define additional files to be compiled or linked into the executable and said that he could demonstrate the full functionality outside the presentation. The GUI support capabilities were already there. M. Bernard asked whether arrays and constants could be defined in a separate file. H. Brouquet assured him that the $INCLUDE file option still worked as before. The user could also create a directory and include it in the model tree. M. Bernard asked about templates. H. Brouquet replied that the user could define a template model file that could be used for all analysis cases.
P. Poinas (ESA/ESTEC) commented that `ESARAD` had capabilities for working with variables, and wondered whether these variables could not be passed to `ESATAN` instead of their computed values as this would improve traceability and parameterisation.
R. Nadalini (Active Space Technologies) asked about the availability of the new interface on Windows XP and Vista. H. Brouquet said that the workbench would be available on the same platforms as the current version, so Vista would be supported with the new compiler.
R. Nadalini commented that the user often needed to select a property or shell from a list, but in the current version these lists appeared to be in random order. He wondered whether it would be possible to sort these lists to make it easier to find things. H. Brouquet admitted that this could be improved. He said that there was a search option already, but they would look at sorting these lists in the future.

1.10 Innovative Ray Tracing Algorithms for Space Thermal Analysis

P. Vueghs (University of Liége) presented the main thrust of his PhD thesis, which looked at speeding up raytracing by replacing multiple calls to Monte Carlo ray-tracing by using a modified ray-tracing hemisphere method. He also described how the raytracing results could be applied to both geometrical primitives and finite element meshes with a new approach to statistical accuracy control. (See appendix J)
T. Soriano (Astrium Satellites) asked how the new algorithm handled specularity. Did it use a combination of view factors instead of ray propagation? P. Vueghs said that the system could handle specularity by including it in the so-called 'extended' view factor. The raytracing in this system was a light operation because it only followed the specularly reflected rays, so it did not add much to the overall computation.
T. Soriano asked whether the direct view and specular reflections were handled in a single pass. If so, how did this relate to the extended view factor calculations? HP. de Koning (ESA/ESTEC) answered that more than one set of extended view factors were calculated when specular reflection needed to be considered, one for each spectral band.

1.11 THERMISOL — New features and demonstration

T. Soriano (Astrium Satellites) gave a brief overview of the module structure within `THERMISOL` and described the modifications that had been made to the `MORTRAN` syntax to simplify some operations for the user, especially event handling, and to support the separation of time and temperature dependent variable updates during the solution run, and to allow adaptive code based on the results at each iteration step. (See appendix K)

M. Bernard (Astrium) asked about the $VTEMPERATURE blocks. Could the user adapt values to have temperature dependent GLs, and GRs? What about heater powers? Would this not be dangerous because the user could not know whether the solution had converged yet. T. Soriano said that this is why the optimisations were needed in order to leave some time for the solution to adapt to the modifications and allow convergence that way.

M. Bernard had a suggestion for the name of the syntax presented in the GUI. The 'New' option should be renamed as 'v431 syntax'. He said that the 'Old' and 'New' distinction was clear in this version, but as new versions were released, maybe with additional changes, the terms would become confusing. The GUI should not use 'Old' and 'New' but should be more explicit.

HP. de Koning (ESA/ESTEC) said that there was a big issue with the language changes here. He felt that this was a repeat of the ESABASE and SYSBAS language situation of 15 years ago. The fact that the ESATAN and THERMISOL languages were now branching could lead to incompatible models in the future. This needed to be addressed. He said that part of the STEP-TAS work had been looking at a neutral representation of models in SINDA, ESATAN and THERMISOL. T. Soriano said that he was also concerned and wanted to keep the differences within strict boundaries. He did not plan to remove the old syntax, so there would still be two ways of doing the analysis within THERMISOL. He said it was important that the time needed to convert a model from ESATAN to THERMISOL should be kept as short as possible, so he wanted to keep these differences within limits.

O. Pin (ESA/ESTEC) asked whether the THERMISOL team planned to provide a means to export these changes to ESATAN. He recalled that the THERMISOL team had been clear at the beginning that the original THERMISOL would never deviate from the ESATAN language. He conceded that for the major changes it was possible that they provided added values, but questioned whether changing the syntax to provide an equivalent form was really useful, e.g. the MORTRAN STATST call. He asked why the THERMISOL team did not provide converters so that the THERMISOL models could be converted to run in ESATAN. T. Soriano said that the STATST change was just more convenient for the users. He argued that ALSTOM had also added new features to the ESATAN language. O. Pin admitted that they had, but argued that it was ALSTOM's language and that ALSTOM had no obligation to implement changes made by other people. C. Theroude (Astrium Satellites) argued that they could not commit to follow ALSTOM's developments to the language for the next 20 years because they didn't know what ALSTOM would do in the future. T. Soriano repeated that they wanted to keep the differences in the language to certain limits so that it would not be time consuming for the user to convert. O. Pin emphasized that ALSTOM had committed that, in principle, models would always be backwards compatible. THERMISOL had now introduced the new VTIME, VTEMPERATURE and VRESULT blocks. Would there be new blocks next year? C. Theroude said that after the discussion at the previous workshop they had kept the old VARIABLES blocks definitions from ALSTOM and had provided new blocks. O. Pin said that all he was asking for was a THERMISOL to ESATAN converter to save the user from making the changes by hand. The tools were not compatible. C. Theroude argued that THERMISOL models were compatible with ESATAN. HP. de Koning said he did not agree and that the issue was black or white, either the tools were compatible or they were not. C. Theroude said that Astrium could not commit to following any ALSTOM changes. He would really prefer to work with a neutral language that also supported other thermal modelling tools such as SINDA. HP. de Koning admitted that this would be better and that STEP-TAS had been designed to make this possible in the future. Exchanging the structure of an ESATAN model ($NODES,

$CONDUCTORS, etc.) was already done in the ESATAP STEP-TAS files, but exchanging the user-defined MORTRAN would be a big challenge. The THERMISOL language was now effectively a branch of the ESATAN language. As long as this situation was clear to the end-users problems would be avoided. The community would speak by using the tools that they liked. He just wanted the situation to be clear: the THERMISOL language was no longer compatible with ESATAN.

1.12 Correlation of ESATAN TMM with Ice Sublimation Test

A. Schubert (Astrium GmbH) presented results of an investigation into the unexpected build up of ice on the stage separation structure during an Ariane-5 launch, and how the sublimation of the ice in flight had cooled the structure below its qualification limit. She described a simple experimental test and a one-dimensional representation of the set-up in ESATAN. (See appendix L)

S. de Palo (Thales Alenia Space) asked whether other software had been considered. Had they considered using a multi-physics software tool to check the results. A. Schubert said that they had not looked at other software yet.

M. Molina (Carlo Gavazzi Space) asked about the slide where the test with the perspex substrate showed a thickness variation that was 3-4 times more than the aluminium. Was there a reason for this? A. Schubert said that she had anticipated this question in a previous version of the presentation, but had not included it here. The reason was that they had measured the water level during filling, and had assumed an uncertainty in the model of +/- 2mm, with a variation of 0.4mm due to the expansion of the ice layer as the water froze. After the first calculation, the ice layer on the aluminium substrate had been reduced by 0.6mm, but they had to increase it in order to keep the thermocouple covered. Therefore the test run had been filled to a higher level, so the minimum thickness was higher. M. Molina asked whether the change in thickness was different for the aluminium and the perspex. A. Schubert said that in the aluminium test there had been a much larger change in thickness.

HP. de Koning (ESA/ESTEC) asked whether they had considered using ice supports for the thermocouples to be prepared in a separate chamber. A. Schubert confirmed that they had thought about this agreed that this could be applied for future tests.

H. Rathjen (Astrium GmbH) said that ESATAN had been used because they had wanted to include it in a stage level model, which was already written in ESATAN.

G. Tonellotto (ESA/ESTEC) asked whether it was only the low temperatures that had been unexpected for the Ariane flight, or was it just the appearance of the ice. A. Schubert answered that they had been expecting temperatures below 0°C, but not the ice sublimation and the colder temperatures that resulted from it as the flight progressed. H. Rathjen said that the ice sublimation had contributed to temperatures 25°C below those expected at the stage separation. HP. de Koning observed that they had been lucky to have sensors there to measure the temperature during flight, otherwise they would never have known about the problem.

Day 2

Wednesday 29th October 2008

2.1 Improved Handling of Thermal Test Results

HP. de Koning (ESA/ESTEC) presented details of work completed since the previous workshop relating to processing thermal test data and analysis predictions using `DynaWorks`. The sensor data was imported in near real-time using simple annotated comma separated value files from the ground based test environment (EGSE) via an FTP server. The `ESATAN` analysis predictions were imported via `STEP-TAS` files. He concluded by announcing a competitive ITT that would open on a similar subject shortly after the workshop. (See appendix M)

S. de Palo (Thales Alenia Space) asked whether the annotated CSV format could be made available for the Herschel test campaign. HP. de Koning answered that, in principle, yes, the format could be made available. People should contact him in order to get help on how to get the activity going. This was standard technology that could be made available to the community. He said that this work had been been shown to be very useful in solving what was a very common problem. He felt it strange that it had not been solved with a common tool or software before now.

J. Persson (ESA/ESTEC) remarked on the 'near real-time' import, and asked whether this was a requirement that had come as a result of Alenia's presentation at a previous workshop. HP. de Koning said that the work had not been targeted at any particular project. The ITT had been used as a way to solicit ideas. Many companies had already looked at this problem and had developed their own systems and procedures. Now it was time to take all of this effort to the next level. There were too many individuals trying to solve the same problem over and over again. He agreed that the work done by Alenia would be useful input.
M. Gorlani (Blue Engineering) asked whether this work related only to mechanical testing. He noted that if someone wanted to include model correlation in the procedure, it might involve a lot of computation time. Was there a need to use reduced or simplified models? HP. de Koning said that reduced models could be one approach. Another would be to just use lots of compute power via a computer cluster. Lots of different solutions were possible, depending on the exact test requirements. The reduced model approach had its advantages, but in reality the goal was to correlate the complete model with the tool. The disadvantage was determining how well the reduced model matched the complete model.

2.2 ESATAP — Distribution and maintenance process

F. Brunetti (DOREA) described the process of registering with the ESATAP support website in order to download the software and access the information there. He encouraged users to file software problem reports via the dedicated forms so that any issues with ESATAP could be addressed and the software improved. Videos on using ESATAP would appear on the website shortly. He informed everyone that training could also be arranged on site as well as in Cannes. (See appendix N)

E. Overbosch (Dutch Space) asked whether DOREA would be able to help with providing the DMPTAS routine on Sun Solaris. F. Brunetti said yes, because although they did not have a binary version available for Solaris, it was just a question of recompiling. DMPTAS was written in C++ and had been designed to be highly portable. On the PC, they had used the MinGW environment. He did not foresee any problem with providing a version for Solaris.

R. Patricio (Active Space Technologies) asked whether the following day's training was open to all. F. Brunetti said he should contact DOREA in order to arrange training. He could offer training at the customer's site, or the customer could have the training in Cannes. O. Pin (ESA/ESTEC) said that ESA would pay for the training in the end from the maintenance budget. O. Pin supposed that F. Brunetti might be more than happy to come to Portugal to give a training to Active Space Technologies. But he felt it might be better to arrange for training for a larger group, at Astrium in Toulouse for example, so that industry would only have to pay for engineering time. In this way the training would remain free for the user. Sdp asked whether the training would be available at all companies. O. Pin said that maybe it would be better for some people to combine their training with that of other companies.

S. de Palo (Thales Alenia Space) remarked that he had already tried to work through some of the small training examples, but had encountered problems when using the Linux version on their servers. It had not been possible to run ESATAP, load the HDF5 file and then save the task. So far they had not been able to solve this problem on Linux, and would probably move to the PC Windows version. F. Brunetti said that this could either be a problem in the licence handling, or a problem with how the tool was being used, and asked him to send a software problem report. He stressed that ESATAP was still a very young product, that had just been released in February, and although they were doing their best it was possible that some things still needed to be fixed. S. de Palo asked whether ESATAP had also been tested as a server distribution. F. Brunetti admitted that this had not been tested at the beginning when ESATAP had been released, but DOREA were working on this in collaboration with ESA. He asked everyone to send software problem reports if they discovered issues so that DOREA would know the exact problems that needed to be fixed.

M. Bernard (Astrium) asked how the licencing worked. Did the user need more than one licence if more than one ESATAP was being run at a time? F. Brunetti answered that one licence meant one machine could run multiple ESATAP sessions in parallel. He said that they were already looking at the issue of having the licence information on a central server for ESA. The central server would still need to have a licence file that contained the host identifiers of all of the machines that needed to run to run ESATAP, so the user would have to register all of those machines. There was no licence server as such: just a file available at some central location that ESATAP could read. M. Bernard asked whether it would be possible to have two ESATAP sessions running on the same machine. F. Brunetti said that would be possible. O. Pin explained that there was no real limitation on the number of licences within a company. ESA only really needed to know who was using ESATAP because of the way the ESA funding rules worked, and to avoid problems with unauthorised users.

2.3 Implementation of the Equation of Time in Sun Synchronous Orbit Modelling and ESARAD Planet Temperature Mapping Error at the Poles

A. Sauer (EADS-Astrium) described the orbital effects that resulted in changes to the solar reference vector, and how these changes could result in significant differences in the environmental heat fluxes calculated. He presented a workaround, using the Equation of Time, that had been applied to the analysis of the MIPAS instrument on Envisat. He then went on to describe a problem that had been discovered in ESARAD for the analysis of spacecraft models in low Earth orbit over the poles, resulting in lower planet fluxes than expected in the polar regions. (See appendix O)

S. Price (Astrium UK) commented that for their Envisat analysis, they had used an ascending node that corresponded to 22:00 $\pm$ 15 minutes. Was the variation that had been present in addition to this 15 minutes or was it encompassed in the 15 minutes? A. Sauer said that they had looked at the timing of the node line plus the equation of time. They had started with the 22:00 $\pm$ 15 requirement but had then needed to add the extra variation.

S. Cuylle (Verhaert Space) asked about the influence of the variation on the solar constant. A. Sauer replied that the solar constant was calculated using the distance of the Earth from the Sun, so it had been calculated correctly.

P. Poinas (ESA/ESTEC) commented on the workaround to the polar temperature mapping problem, and said that the same behaviour could be achieved by imposing the temperatures on the planet instead of allowing ESARAD to calculate the temperatures for a smaller mesh. A. Sauer said he did not know whether this had been investigated because a colleague had done the analysis. P. Poinas said that the planet flux depended on the mesh used and the interpolation of the temperature of the elements. The problem could be solved by using a finer mesh and by adjusting the temperature of the polar element to take the polar singularity into account.

S. Höfner (Max Planck Institute) asked whether the incorrect planet flux calulation over the poles had been observed in orbits higher than 50km. A. Sauer said that they had only looked at the low Earth orbit case.

S. Price asked which version of ESARAD had this problem. H. Beaumont (ALSTOM) said that it had been discovered in ESARAD-6.2.1. H. Brouquet (ALSTOM) noted that the problem would be corrected in the release at the end of the year.

2.4 TCDT — New Features

M. Gorlani (Blue Engineering) presented the background to the Thermal Concept Design Tool, a brief overview of the types of companies that had requested to download the TCDT, and their locations. He said that they had conducted the first user survey, and he listed some of the enhancements that had been suggested. He gave a demonstration of some of the improvements that had already been made to correct the problems where the different worksheets were not updated automatically as changes were made. (See appendix P)

C. Kirtley (ALSTOM) asked about the data loaded back into the TCDT after the ESARAD or ESATAN analysis runs. M. Gorlani said that after the ESARAD run, the TCDT extracted the GRs in order to build the model that could be used with either ThermXL or ESATAN. After the ESATAN run, the TCDT extracted the temperatures from the comma separated value output file. The user could copy them from the data sheet directly into ThermXL.

O. Pin (ESA/ESTEC) announced that ESA had published ARTIFIS and TOPIC on the exchange web site free of charge. They had been made available, but had never been announced. The TCDT made use of ARTIFIS and TOPIC, and that was the reason why he was announcing their availability now. D. Gibson (ESA/ESTEC) reminded everyone that ARTIFIS and TOPIC were available 'as is' but were not supported or under active development.

2.5 Applicability of EcosimPro to simulate a Life Support System

V. Guirado (NTE) outlined work carried out in his previous job at NTE on the preliminary design of a life support system for a future Moon base. The three main sub-systems were the MELISSA waste recycling and food production compartments, the air revitalization system (ARES), and the grey water treatment unit (GWTU). These systems were modelled using EcosimPro. (See appendix Q)
V. Guirado had created the component library himself, and J. Etchells (ESA/ESTEC) asked him whether he was aware that an ECLSS library already existed, or had he developed his own library because he needed additional components? V. Guirado said that the standard ECLSS library was mainly concerned with dynamic analysis, and it would have been difficult to use them for a steady state analysis case, so he had created his own components.

2.6 ALSTOM Product Demonstration

I. Guest (ALSTOM) presented further information about the new ESATAN-TMS workbench. He skipped over the basic features that had already been shown in earlier presentations. He described how the different tools had been brought together under a utilities menu, how to generate the results files in HDF5 format and the benefits that the new format gave, improvements to the Crank-Nicolson solver, error reporting and post-processing using ThermNV. (See appendix R)

The computer had needed to be restarted in the middle of the demonstration, so S. Cuylle (Verhaert Space) commented that such problems were not new, and expressed his concern that stability still seemed to be an issue. I. Guest countered by saying that he was demonstrating a beta version of the software, and that he had been through this demonstration at least twenty times previously, and that this was the first time he had experienced such a problem. H. Brouquet (ALSTOM) explained that the Windows blue screen problem was due to memory problems with the laptop, and not with the software. S. Cuylle argued that the problems he had witnessed, both yesterday and today, were just like the problems that he experienced on a regular basis. H. Brouquet argued that the demonstration involved the development version of the software. He said that most users would agree that the stability of the tools had improved greatly over the past few years and that they did not normally see crashes like the one they had just observed.

R. Patricio (Active Space Technologies) observed that the previous day P. Poinas (ESA/ESTEC) had asked about parameterised properties in ESARAD and whether it was possible to propagate them into the ESATAN model. When the user did a parametric analysis, were alpha and epsilon also handled? I. Guest said that they were. C. Kirtley (ALSTOM) explained that the parametric analysis worked with the ESATAN model, so the user could always vary the parameters withing the ESATAN model.

R. Nadalini (Active Space Technologies) assumed that the new ESATAN-TMS system required less intervention in the ESATAN model. I. Guest agreed. R. Nadalini noted that in the current version of ESARAD, the automatic conductor generation could create conductive lines that were not always accepted by ESATAN. He had observed this problem in ESARAD-6.2 and ESATAN-10.2. H. Brouquet said that this was a known problem, and that ALSTOM had changed the way that the GL statement was generated, so this problem should be solved in the new release.

R. Patricio asked whether the cross comparison feature in ThermXL allowed the user to select root sum squares, and if not, whether the user could program something to handle them. C. Kirtley said that in the cross comparison report the user could do that. R. Patricio supposed that if he had five different cases he could get a report with a single root sum square value. C. Kirtley confirmed that it should be possible.

2.7 Implementation of a Mars thermal environment model using standard spacecraft analysis tools

A. Quinn (Astrium UK) described the methods that had been developed to use ESARAD for the analysis of a model of a Mars rover on the surface of the planet. They had used an external tool to calculate various aspects of the Martian atmosphere and environment. The geometrical model consisted of the rover and the immediate surface, and was rotated and positioned to correspond to the appropriate Martian latitude and longitude. Additional work had been needed to handle the effects of the atmosphere and the ground under the rover. (See appendix S)

J. Etchells (ESA/ESTEC) asked about the convection correlations that had been mentioned. The Mars atmosphere contained a lot of carbon dioxide and was at a much lower pressure than the correlations he had seen, which were all derived from terrestrial applications. He wondered whether current values of the Grashof number, etc. were still valid on Mars. A. Quinn said that they were using the numbers from the terrestrial applications. J. Etchells asked whether they had considered calculating the heat transfer coefficients using CFD analysis. A. Quinn replied that they had considered it, but did not currently have either the tools or the expertise in-house.

HP. de Koning (ESA/ESTEC) observed that the real Mars environment experts where the people at NASA/JPL. He wondered whether there had been any contact with them as it could prove to be useful because they might have very useful data that could be used to validate the model.

R. Nadalini (Active Space Technologies) asked whether the LMD tool[1] had been integrated into ESATAN. A. Quinn said they used the tool to output values for the day of interest, and then integrated these values into ESATAN as arrays. He was asked why they had not used the Mars Climate Database. A. Quinn explained that the Mars Climate Database was really intended for supercomputing applications for dynamic climate modelling, and that they had only needed a small amount of data for specific locations and conditions, and to be able to run within ESATAN on a normal PC or workstation. R. Nadalini asked whether it would be possible for other groups to have access to the tool. A. Quinn said that he did not see any reason why not, but it was an ESA tool so the question should really be directed at ESA.

S. de Palo (Thales Alenia Space) asked whether the tool was also available for modelling the Earth. HP. de Koning said that he was not sure, but the person to ask in ESA would be Eamonn Daly of the Space Environment and Effects group.

[1]Tool created at the Laboratoire de Météororologie Dynamique in Paris under ESA contract

2.8 Thermal Design and Analysis of the BroadBand Radiometer

O. Poyntz-Wright (RAL) presented details of the BroadBand Radiometer, a British-built instrument that would fly on ESA's EarthCARE mission. He explained the requirements and the thermal model that had been developed for the analysis. He described enhancements to the tools that would have simplified the analysis, and outlined the future plans for a more detailed instrument model and further analysis work. (See appendix T)

E. Overbosch (Dutch Space) asked about the stability control of the heaters. Was it a simple on/off system or was it based on PID controllers? O. Poyntz-Wright said that so far they had only used a simple system where the heaters were either completely on, or were completely off. E. Overbosch expressed surprise that they had been able to achieve that level of stability with such a simple system. That was very good.

M. Gorlani (Blue Engineering) asked why they had decided to create the `ESARAD` and `ESATAN` models by hand rather than use a CAD tool. O. Poyntz-Wright said that it was basically down to personal preference, and admitted that he had no experience of importing a CAD model and so had preferred to build a simple model and add detail to it as required.

2.9 STEP-TAS Activities

E. Lèbegue (CSTB) presented the goals and progress of the IITAS project to provide an industrial implementation of the `STEP-TAS` protocols in the main European thermal tools, and the real world models that would be made publically available for use in validation. His company provided the `C++` software development kit and the graphical validation tool `BagheraView`. (See appendix U.1)

A. Fagot (DOREA) described the `TASTMM` project and its goals to provide an interface to thermal mathematical model data using `STEP-TAS` in both the ASCII Part-21 format and in the binary HDF5 format as this was much more compact and efficient. (See appendix U.2)

HP. de Koning (ESA/ESTEC) gave a brief overview of the other `STEP-TAS` developments that were in progress and the plan for 2009, including work on kinematics and mission aspects, representation of thermal mathematical models, standardisation, and foreseen `STEP-TAS` interfaces in `TMG` and some of the US tools. (See appendix U.3)

M. Gorlani (Blue Engineering) asked whether the real models that would be used to test the converters would be made public [they would] and asked whether it would be possible to obtain the beta versions of the converters. HP. de Koning said that it was still too early to release the beta versions, but said that if companies were interested to help in the testing, then it would probably be possible within a few months. All test models would indeed become available for public access. He said that validation would involve a `THERMICA` model produced by EADS Astrium in Friedrichshafen, an `ESARAD` model produced by RAL, and a `CIGAL2` model produced by Thales Alenia Space in Cannes. The idea was that every partner developed one model that would be made public, with no issues about IPR. These models could also be useful for testing other software.

S. de Palo (Thales Alenia Space) remarked about the screenshot that had shown `BagheraView` and `TASverter`. E. Lèbegue said that the release schedule for `BagheraView` was the same as for the converters. They were still validating and consolidating all of the work done, and the release would probably take place in the middle of next year. He said that a beta release of `BagheraView` that used the old version of `STEP-TAS` was available for anyone who was prepared to search on Google for it. HP. de Koning observed that one interesting point about this version of BagheraView was that it was also able to import both STEP AP-203 and AP-214 files, and could be used to compare models and to do a visual overlay inspection of a model.

2.10 Thales Alenia Space thermal software suite — Presentation of the tools and current policy

T. Basset (Thales Alenia Space) gave a brief history of the thermal tool development in Cannes, and the evolution of the different tools over the past 30 years. F. Brunetti (DOREA) narrated an animation showing the process of building a simple model using CIGAL2. JP. Dudon (Thales Alenia Space) described the background to the 3D conductive tool, the computation of elementary conductive couplings, the reduction of a finite element model and the generation of the equivalent thermal model. F. Brunetti narrated another animation showing the visualisation of temperatures on both the finite element, and lumped parameter representations of the same model. T. Basset then announced that they were making the tool available for free to anyone who wanted to use it, and that CDs were available with a two month trial licence so that people could evaluate the tool for themselves. (See appendix V)

HP. de Koning (ESA/ESTEC) had noted that they intended to release the 3D conductor calculation tool, and asked whether this would also support all of the STEP-TAS conductor links as well. T. Basset said that it was possible to export the links to ESATAN. JP. Dudon said that it was possible to output in a format suitable for ESATAN, but they had not considered STEP-TAS.

P. Vueghs (University of Liége) had noted that description of the finite element mesh and how it was possible to fuse a finite element to a geometrical element. He wondered whether they had access to the real geometry. JP. Dudon explained that CORATHERM only considered the facetted geometry mesh. However, the mesh was parameterised so that it was possible to adapt it.

S. de Palo (Thales Alenia Space) asked whether IGES import was available as part of CIGAL2. And how were the temperature mappings handled? JP. Dudon said that CIGAL2 was just a pre- and post-processor with modules from OpenCASCADE providing the IGES import facilities. S. de Palo asked whether it was possible to export to FEM. JP. Dudon said that there was an export to STEP-TAS. S. de Palo asked how they were able to export the temperatures for the lumped parameter model and then convert back to the finite element model. JP. Dudon explained that they used a very simple format, an internal FORTRAN format, that was used specifically for CIGAL2.

H. Rooijackers (ESA/ESTEC) asked about the platforms on which CIGAL2 could be run. F. Brunetti said that the CD contained a version that would run on Windows Vista and XP. Everything had been implemented so that it could be compiled on Unix, so it would not be a big effort to compile a version for Unix if required.

2.11 Workshop Close

H. Rooijackers (ESA/ESTEC) remarked that this year there had been an increase in the number of presentations, and also an increase in the quality of presentations. He wanted to thank all of the authors and presenters, and all of the other participants, and hoped to see everyone at the following workshop.

Appendix A

Welcome and Introduction

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Appendix B

Columbus Thermal Control System On-Orbit Performance

Jan Persson
(ESA/ESTEC, The Netherlands)

Zoltan Szigetvari
(EADS Astrium, Germany)

Gaetano Bufano
(Thales Alenia Space, Italy)

Abstract

The Columbus laboratory module, a major European contribution to the International Space Station, was launched onboard the Space Shuttle Atlantis on 7 February 2008. The presentation will present some early data on the performance of the Columbus thermal control, both active and passive, after start of on-orbit operations. The data will be compared to a set of analysis results from the Columbus Integrated Overall Thermal Mathematical Model (IOTMM), which have been produced with the observed ISS on-orbit conditions as input.

Appendix C

Experience of High Accuracy Thermal Modelling from the LISA Pathfinder Thermal Noise Analysis

Nick Fishwick Simon Barraclough
(EADS Astrium, United Kingdom)

Abstract

The increasing accuracies of the thermal stability of space science missions requires that thermal models of the instrument payloads need to have higher stability requirements. The Lisa Pathfinder technology demonstration mission for detecting gravity waves is one such sensitive mission with changes in temperature of 10^{-6} K being significant to the payload. Following on from the work by Ulrich Rauscher on Guidelines for High Accuracy Thermal Modelling (presented at the 21st Workshop last year) the implementation of Double Precision values in ESATAN has been investigated with Lisa Pathfinder. The study of the variations on temperature convergence and the Power Spectral Density analysis of the identified Thermal Noise sources on the mission have shown that the payload meets the temperature requirements of 10^{-3} K $Hz^{-1/2}$.

Appendix D

New Technology for Modeling and Solving Radiative Heat Transfer using TMG

Christian Ruel
(MAYA, Canada)

Abstract

As engineers increasingly rely on numerical models within the framework of a collaborative development process, demands on solution performance are becoming much more severe. In order to effectively address these demands, we believe that a massive, quantum improvement in the solution speed of spacecraft thermal analysis systems is required. To achieve such a breakthrough, MAYA has undertaken the parallelization of the TMG software system, enabling full exploitation of multiprocessing computer environments (consisting of multiprocessor servers or networked workstations or clusters).
Maya is also developing an innovative numerical method for the simulation of radiative heat transfer in cryogenic systems, based on the radiosity method, in which the radiating spectrum is discretized into spectral bands. A surface at a given temperature will radiate and absorb in all the bands, but the coefficients of emissivity and absorptivity - while equal to each other in a given band - will vary from one band to the next.

Appendix E

The ESATAN Thermal Suite

Chris Kirtley
(ALSTOM, United Kingdom)

Abstract

Overview of the status of the ESATAN Thermal Suite including user support and development plans.

Appendix F

Stability Analysis in the Columbus Active Thermal Control System

Tor Klingberg
(ESA/ESTEC, The Netherlands)

Abstract

Using analytical control theory and ESATAN simulation to analyze the stability margin of the Columbus ATCS under different conditions.

Appendix G

THERMICA
On-going research and developments

Timothée Soriano
(EADS Astrium, France)

Abstract

SYSTEMA: The THERMICA framework
Since the version available last year (4.2.3), the current release offers new functionalities:

- New framework based on QT technology
- Boolean Shapes
- Multi-kinematics and sequences management
- Video recording

+ Presentation of some on-going developments for the next release.

THERMICA 4.3.1

- Extended for the new SYSTEMA functionalities
- Integrate maps for planet properties and/or night/day temperatures definition for the IR flux
- Integrate the new conductive method: the RCN

  The Reduced Conductive Network is a new method compatible with the radiative mesh and can also be used for better convergence finite elements methods as well.
  The main idea of the RCN method is to determine a sub-space of linearly equivalent results and to find a particular solution from this sub-space. This solution provides some particular properties which make it compatible with radiative aspects and is given by the limit of a specific function.

+ Presentation of some on-going developments for the next release.

Appendix H

A Software Tool Applying Linear Control Methods to Satellite Thermal Analysis

Martin Altenburg Johannes Burkhardt
(EADS Astrium, Germany)

Abstract

The presentation discusses the development of the software tool TransFAST, which firstly transfers the classical thermal network to a standard linear control system, and subsequently solves this system in the frequency domain. Application of this type of analysis becomes more and more important for 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. As a major advantage, thermal stability analyses can be performed without running extensive transient thermal analysis, delivering reasonable and even more accurate results, compared to the classical approach, and in general with significantly less effort.
For solving one key issue, the inversion of the system matrix, the presentation discusses two different numerical approaches, the direct inversion of the transformed system matrix (DIT) and the conditioned evaluation of the frequency response (CEF). A comparison of the different methods is provided for the application example LISA. For this mission, requirements imposed on the satellite system design and/or on the scientific payload design are defined in the frequency domain because these requirements have to be met for a certain measurement bandwidth only. Mission specific requirements are typically expressed in terms of $quantity/\sqrt{Hz}$, the so-called linear spectral density, in analogy to the power spectral density, i.e. $quantity^2/Hz$.
TransFAST also comprises powerful post-processing features for graphical output, which allows checking the analysis results directly after the calculation is performed. As a further feature of this software the user can import also results from external sources like ESATAN for further post- processing.

Appendix I

ALSTOM Product Developments

Henri Brouquet
(ALSTOM, United Kingdom)

Abstract

Overview of new features introduced in the latest versions of the products.

Appendix J

Innovative Ray Tracing Algorithms for Space Thermal Analysis

Pierre Vueghs
(University of Liége, Belgium)

Abstract

The objective of the presentation is to give a short overview of the Ph.D. thesis entitled Innovative Ray Tracing Algorithms for Space Thermal Analysis, performed at the University of Liège in Belgium, with the support of ESA and the Belgian National Fund for Scientific Research (FNRS). In this presentation, we will mention the requirements that the final algorithm must fulfil; we will briefly present some key elements of the developed method, such as the hemisphere method, the combination of geometrical primitives with finite element meshes, statistical accuracy control and report. The validation aspects are then covered with comparison with analytical cases and industrial-ESARAD type models.

Appendix K

THERMISOL
New features and demonstration

Timothée Soriano
(EADS Astrium, France)

Abstract

Brief presentation of THERMISOL modules:

- Skeleton generator and expander
- Input file pre-processor (reader)
- Solver library
- Post-processing tools: Posther & B-Plot

Brief presentation of new features in THERMISOL 4.3.1

- Extension of implicit Mortran syntax
- Extension of the node specifications of output subroutines
- Automatic conversions of single floats to double precision floats
- New executive blocks: $VTEMPERATURE / $VTIME / $VRESULT
- Management of time events

Demonstration: Example of cold/hot cases study
Using a simplified model of a satellite, we will compute the temperatures in cold and hot case.

Appendix L

Correlation of ESATAN TMM with Ice Sublimation Test

Anna Schubert
(EADS Astrium, Germany)

Abstract

During ascent of a previous ARIANE 5 launcher, the stage separation system (SSS) of the cryogenic upper stage (ESCA) exceeded its qualified lower temperature limit at the event of stage separation. Although a proper stage separation could be achieved for that flight, detailed studies followed this unexpected cold temperature drop. These investigations identified the formation of frost/ice on ground and its subsequent sublimation during ascent as the important contribution to the observed phenomenon. Consequently, counteractive measures have been successfully applied for subsequent flights, where up to now a temperature limit violation of the SSS has never been encountered again. For a better understanding of the sublimation effects which were caused by the ice layer on the launcher structure, sublimation tests have been performed. In these tests, an ice layer was applied on two different substrates, one of Plexiglas and one of Aluminium, which were equipped with thermocouples. The test setup was then placed in a vacuum chamber, which was evacuated, causing sublimation of the upper ice layer. During the evacuation, the pressure in the chamber was recorded, and the temperatures were measured in different positions in the ice layer and on both substrate surfaces.

In order to establish a correlation of thermal analyses with the results of the a.m. tests, two small thermal mathematical models (TMMs) were established with ESATAN, one for ice on Aluminium and one for ice on Plexiglas. They represent both the substrate and the ice layer and regard the sublimation heat flux through both, based on the pressure dependent sublimation mass flow rate. Both for the ice on Plexiglas and the ice on Aluminium, the results of the calculations show a very good overall accordance with the measured test results. The applied model, which is the focus of this presentation, is based on the Hertz-Knudsen relation with an evaporation coefficient of $\gamma = 0.3$, where the temperature dependent vapour pressure of ice is respected according to the Goff-Gratch-Equation.

Appendix M

Improved Handling of Thermal Test Results

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

Etiènne Cavro
(Intespace, France)

Abstract

Last year Intespace implemented under ESA contract in DynaWorks a number of features to improve the processing of thermal test results. This presentation will show what they were and discuss further work in this area.
The improvements focussed on:

- Simple, near-realtime import of EGSE sensor data;
- Import of ESATAN analysis predictions into DynaWorks, so that predictions and life test results could be compared interactively;
- Archiving of complete thermal test campaigns for future post-test consultation.

The improvements will be illustrated at hand of real test campaigns in which the new features were validated.

Appendix N

ESATAP
Distribution and maintenance process

François Brunetti
(DOREA, France)

Abstract

After having finalized the first industrial version of ESATAP early 2008, the Thermal Post Processing tool funded by ESA and developed by DOREA, a dedicated website is now available. This presentation shows the distribution procedures and online materials: hot-line, bug tracking system, FAQ, training courses and videos are now available for thermal users.

Appendix O

Implementation of the Equation of Time in Sun Synchronous Orbit Modelling and ESARAD Planet Temperature Mapping Error at the Poles

Arne Sauer
(EADS Astrium, Germany)

Abstract

The Equation of Time describes the change of the solar reference vector causing a virtual sun movement (i.e. noon point) due to orbital effects. This has effects on the difference between True and Mean Local Solar Time causing inaccuracies of up to 16 minutes Local Solar Time or $\backsim 4^\circ$ of Ω (RAAN).
In the course of the MIPAS instrument thermal analysis (ENVISAT Mission Extension) it showed how important it is to know the exact angle of the Solar Vector because it had to be assessed if optical components inside of baffles and radiators have solar incidence, due to the degraded ENVISAT orbit. For this reason the Equation of Time had to be considered. It showed that the thermal software did not consider this virtual sun movement. For this reason a workaround had to be established considering the date dependant Equation of Time and the resulting difference between Mean and True Local Solar Time.
In the course of the presentation the Equation of Time will be explained, as well as the mission related problems caused by the non-consideration of the EoT. The workaround will be presented, related to the different thermal software tools THERMICA and ESARAD.
Additionally to this issue a problem will be presented related to mapping of planet temperature and its effect on sun synchronous dawn/dusk orbits. Due to the variation of distance between longitudes from pole to pole and the circular pole elements, the planet temperatures are mapped to varying element surfaces, causing erroneous flux variations along a dawn/dusk orbit with a local minimum at the poles. This problem will be presented accompanied with the workaround to minimize the flux error.

Appendix P

TCDT
New features

Matteo Gorlani
(Blue Engineering, Italy)

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Abstract

The new features that are currently under development for the TCDT will be presented.

Appendix Q

Applicability of EcosimPro to simulate a Life Support System

Victor Guirado Viedma
(NTE, Spain)

Abstract

The project MELiSSA Adaptation for Space Phase II (ESTEC/contract 20104/06/NL/CP) carried out by NTE (Barcelona, Spain) consists of finding a preliminary design of a Life Support System (ECLSS) for a future Moon base providing 100% air closure, 90% water closure and a 5% food production first and a 40% food production in a second steps. The study is mainly based on MELiSSA know-how but using as well other European sub-systems as the Air REvistalisation System (ARES), the Gray Water Treatment Unit (GWTU) and the Urine Treatment Unit (UTU). In our modeling approach, each of these sub-systems is composed of several components that can actually be combined and joined to finally obtain a robust and efficient ECLSS.

These different sub-sytems have been modeled at component level and interconnected using EcosimPro to generate a mass balance static model. Using this software tool, several designs have been created and simulated in order to evaluate which configuration is the most appropriated regarding efficiency, size, mass and energy consumption (i.e ALISSE criteria).

The implementation of a mathematic model for each component has been one of the more important and difficult steps. The difficulty came not only due to the complexity of the processes that take place but also due to the fact that many technologies are under study and several assumptions had to be done. This issue specifically raised the management of the degree of confidence and the need to add specific function for uncertainties calculations.

Another difficulty turned up when the whole system was closed due to the algebraic loops and because the EcosimPro mathematic solver needs the indication of which are the variables to iterate to find a solution to the equation system.

In the European Workshop on Thermal and ECLS Software, it is intended to expose in general terms how the EcosimPro works, how it has been used, as well as the difficulties found and the solutions performed.

The library created in EcosimPro contains the models of several subsystems for different ECLS technologies, and endeavors to be a tool base to develop more sophisticated models, which will allow system engineers to evaluate ECLSS architecture and anticipate the ALISSE criteria.

Appendix R

ALSTOM Product Demonstration

Ian Guest
(ALSTOM, United Kingdom)

Abstract

Demonstration of the latest versions of the products.

Appendix S

Implementation of a Mars thermal environment model using standard spacecraft analysis tools

Andy Quinn
(EADS Astrium, United Kingdom)

Abstract

A number of models of the surface of Mars exist which can be used as inputs to thermal analysis. On ExoMars ESATAN and ESARAD have been used along with a simplified one dimensional Mars climate model supplied by the Laboratoire de Météororologie Dynamique in Paris. These tools can be used to generate flux profiles including diffuse load due to atmospheric dust, dynamic ground temperatures which take into account shadowing and soil thermal response, and representative diurnal cycles. The methods for achieving these are presented here.

Appendix T

Thermal Design and Analysis of the BroadBand Radiometer

Oliver Poyntz-Wright
(Rutherford Appleton Laboratory, United Kingdom)

Abstract

The Broadband Radiometer is being designed and built by a UK consortium to fly on ESAs EarthCARE mission. The Rutherford Appleton Laboratory is responsible for the thermal, mechanical and optical design as well as procurement of critical components. The thermal design has undergone much iteration over the course of 2008. The thermal, mechanical and optical models have now converged on a solution that is being put forward for System Requirements Review in November 2008. Key challenges faced by the thermal design include overcoming the high Earth and albedo loads of a low orbit to passively cool internal black bodies to -10°C and achieving tight stability requirements on the three telescope assemblies. ESARAD and ESATAN models were created to model the low earth orbit radiative environment and the instrument thermal design.

Appendix U

STEP-TAS Activities

Abstract

This is a combined presentation. We will inform you about the progress that has been made in the past year on the following projects:

- IITAS (Industrial Implementation of STEP-TAS) in which Alstom Aerospace, Astrium Satellites (Toulouse) and Thales Alenia Space implement STEP-TAS import/export facilities in their respective tools ESARAD, THERMICA and CIGAL-2 under the lead of CSTB with assistance from DOREA. CSTB has also developed a light C++ software development kit for STEP-TAS and produced new releases of the graphical validation tool BagheraView.
- TASTMM in which DOREA is further developing foundations for the STEP-TAS software libraries and ESATAN / SINDA model exchange.
- TASverter in which ESA TEC-MCV is further validating and completing the STEP-TAS standard, now mainly for the exchange of space kinematic models and space mission aspects.

Also a brief outlook will be given on what to expect in the coming year.

Appendix V

Thales Alenia Space thermal software suite
Presentation of the tools and current policy

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

François Brunetti
(DOREA, France)

Abstract

In this paper Thales Alenia Space presents a rapid overview of its thermal software suite developed and used in the site of Cannes. In particular the objective is to announce the free distribution of CIGAL2, the pre and post processing tool dedicated to radiative and conductive modelling. This distribution will be done via CD-ROMs available on site. After a brief presentation of our main in-house tools, we make a demonstration of the last release of CIGAL2. We then focus on the 3D conductive module with a short demo and we conclude by a rapid presentation of Thales Alenia Spaces policy about the development and distribution of the complete conductive chain.

Appendix W

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