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November 2001

**15th European Workshop on
Thermal and ECLS Software**

ESTEC, Noordwijk, The Netherlands

9-10 October 2001

ABSTRACT

This document contains the minutes of the Fifteenth European Thermal and ECLS Software Workshop held at ESTEC, Noordwijk, The Netherlands on the 9th and 10th October 2001. 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 related documents.

Table 1: Printing History

Release	Date of issue	Reason
1.0	2001-10-29	Document creation
1.1	2001-11-23	Incorporated internal comments

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Final Programme

15th Thermal and ECLS Software Workshop
 ESTEC, Noordwijk, The Netherlands
 9th-10th October 2001

Tuesday 9th October 2001

09:30	Registration	
10:15	Welcome and Introduction	O.Pin ESTEC/TOS-MCV
10:15	Managing the Interface between ThermXL and Esarad	A Robson Astrium-UK
10:45	An Introduction to G-DELTAN C3 - An Interactive Thermal Analysis Tool	C Williamson Eutelsat S.A.
11:15	Coffee	
11:40	Improving Ray-Tracing Algorithm for Monte Carlo Simulations	B Shaughnessy Rutherford Appleton Laboratory
12:00	New Ray-Tracing Technique for Thermica	M Jacquiau Astrium-F
12:20	Report on TFAWS and Introduction to ThermPlot	HP de Koning ESTEC/TOS-MCV
12:50	Lunch	
14:00	Artifis / Topic / ThermXL	F du Laurens d'Oiselay Alstom Power Technology Centre
14:45	Stochastic Approach to Spacecraft Thermal Control Subsystem	F Lamela Herrera CASA
15:30	Coffee	
15:45	ESARAD	F du Laurens d'Oiselay Alstom Power Technology Centre
17:15	Round Table Discussion	HP de Koning ESTEC/TOS-MCV
18:30	Cocktails and Demos	

Wednesday 10th October 2001

09:30	Temperature Control Loop Analyzer (TeCLA) Software	F Burzagli Alenia Spazio
10:00	Analysis of Spacecraft Thermal Stability	B Shaughnessy Rutherford Appleton Laboratory
10:30	An Overview of Bepi-Colombo Thermal Analysis	A Renouf Astrium-UK
11:00	Coffee	
11:20	Application of CORATHERM for Spacecraft Thermo-Elastic Analysis	JP Dudon Alcatel Cannes
11:50	Transient CPL modelling with ESATAN/FHTS and SINDA/FLUINT	C PUILLET CNES
12:20	Status on Model Data Exchange	HP de Koning ESTEC/TOS-MCV
12:50	Lunch	
14:00	Thermica v4	P Renard Astrium-SAS
14:45	Developments in ESARAD, ESATAN and User Support	F du Laurens d'Oiselay Alstom Power Technology Centre
15:45	Workshop Close	O Pin ESTEC/TOS-MCV

1. Tuesday 9th October: Morning Session

1.1. Welcome and Introduction

O. Pin (ESTEC) welcomed everyone to the workshop, and said that he appreciated the effort that people had made in coming, in spite of recent international events¹. He described the aims and structure of the workshop. (See Appendix A)

He explained that the workshop was intended to have three main purposes:

- allow an exchange of views on the use of thermal analysis software
- provide a forum for contact between the developers and the users
- present new versions of the software and get feedback from the users

He introduced the teams from ESTEC and Alstom.

He explained the change in the format of the workshop away from presentations only to having mornings dedicated to such presentations, with more informal software demonstrations in the afternoons. The round table discussion would move to the end of the first day rather than the end of the workshop when many people had to rush for flights. Topics for discussion had derived from questionnaire answers received prior to the workshop.

He informed everyone that 5 PCs had been set up at the back of the room, each with a different software tool, and people were encouraged to play with the tools and ask for demonstrations and help as appropriate.

He reminded everyone about the ICES conference in 2002, and that the deadline for the receipt of abstracts had almost arrived.

1.2. Managing the Interface between ThermXL and ESARAD

A. Robson (Astrium-UK) presented details of working with both ESARAD and ThermXL and the requirements and problems of transferring information between the two. (See Appendix B)

F. du Laurens (Alstom) noted that the presentation had involved the use of ThermXL version 1.0. He said that ThermXL version 2.0 would be demonstrated later in the day, and this version did have an ESATAN file export facility. O. Pin (ESTEC) said the ESATAN export facility provided a static view of the nodes. It was not possible to export the time and temperature formula for each conductor, so it was difficult to model variable conductors. However, the software would highlight any areas where there might be problems with the conversion. F. du Laurens said that ThermXL version 2.0 was now undergoing final testing, and would be available shortly.

O. Pin said that one of the current ESARAD developments was an export facility so that data

1. The attack on the World Trade Center in New York on the 11th September 2001.

could be imported into tools such as ThermXL. A work package to import such files into ThermXL was currently being defined.

P. Poinas (ESTEC) asked whether there was an ESATAN import facility. He felt that ThermXL was a tool for local analysis, and he didn't see any point in exporting a 10-node model to ESATAN, but he could see the need for extracting a set of nodes from an ESATAN file. A. Robson said that the main reason to improve the interface between the tools was the move from the quick design sizing analysis, where the model tended to develop quickly, but then it was difficult to convert from ThermXL to ESATAN. O. Pin said that he took P. Poinas' point and that ESTEC would look into the matter.

O. Pin asked whether anyone else had used ThermXL. M. Molina (Carlo Gavazzi Space) said that he had tried, but had been unable to run it. O. Pin asked whether the PC was configured with an Italian environment, with comma as the decimal separator, but M. Molina said that the PC was configured with the UK environment. E. Cosson (EADS) said he had used it, but had experienced slight problems. O. Pin reminded everyone that there was a known problem of using a comma as the decimal separator for those machines with non-UK settings. S. Kasper (Jena-Optronik) said that he had been using ThermXL without any problems.

1.3. An Introduction to G-DELTAN V3 - An Interactive Thermal Analysis Tool

C. Williamson (Eutelsat) described the development of a simple thermal analysis tool which interpreted the input data and which didn't require a compilation stage. He also gave a demonstration of the tool. (See Appendix C)

P. van Leijenhorst (Fokker Space) asked whether it was possible to use G-DELTAN to perform a complete thermal analysis without plotting any data, and then plot the areas of interest afterwards. C. Williamson said that it was. P. van Leijenhorst asked whether the whole of the analysis could be saved for use at a later time. C. Williamson said it was, and that all data could be saved to disk, including the text.

O. Pin (ESTEC) asked why there was a 500 node limit. C. Williamson answered that it was a relatively arbitrary limit, although he had found that the software became less and less efficient as the arrays became larger. The solver ignored unused node numbers in the input.

J. Persson (ESTEC) asked whether it was possible to generate conductors in the nodal breakdown when using the autogen function. C. Williamson said that it was possible for simple shapes. J. Persson asked which shapes were supported. C. Williamson said that for nodes and conductors the supported shapes were rectangles, cylinders, disks, fins and loops.

O. Pin asked whether it was transparent what algorithms were used. C. Williamson said that the user entered the properties for the nodes, and then the software used a simple iteration technique rather than a specific algorithm.

O. Pin asked whether it was possible to have a variable conductor depending on the temperature when using autogen. C. Williamson said that it was not possible when using autogen, but it was

possible elsewhere.

M. Molina (Carlo Gavazzi Space) asked what was the suggested size of model which could be handled by the software. He realized that there was a limit of 500 nodes, but wanted to what number was best. C. Williamson admitted that he didn't have any empirical data on this, but would guess that 300 nodes probably the optimum number.

M. Molina asked why the software had been developed when MINITAN had already been available. C. Williamson said that he now had a role as a customer rather than a sub-contractor, and often needed to do simple analysis. O. Pin felt that G-DELTAN was not really like MINITAN. It was more like ThermXL because it provided real-time plotting capabilities. C. Williamson admitted that it was possible to do a lot of things using Excel, but felt that the overhead of using Excel made any analysis slow.

M. Molina asked what plans there were for distribution of the software once the beta testing had been completed. C. Williamson answered that there were no definite plans at the moment. M. Molina asked whether it would be possible to distribute the software outside the company. C. Williamson said that it would be possible because it was his software.

P. Poinas (ESTEC) asked whether there had been any comparison of the speed of G-DELTAN compared to ESATAN. C. Williamson said that you had to be careful in making any such comparison. ESATAN was optimised for larger models. G-DELTAN wasn't intended to replace ESATAN. G-DELTAN was intended to be a tool for quick analysis. There was a hole between using hand calculations and using ESATAN. G-DELTAN was a head-start into filling this hole.

P. Poinas asked whether it wouldn't be possible to reduce ESATAN run times by reducing the sizes of the arrays used. C. Williamson felt that he could not really comment on ESATAN. G-DELTAN could use small arrays because it was intended for small models. O. Pin said that ESATAN runs involved a lot of overhead. A lot of checking had to be done because, for example, the user could switch on nodes in each iteration. All of this checking took time. He admitted that the ESATAN solvers were old, and agreed that there might be a need to look at whether more modern solvers and software techniques might be better and faster.

P. Poinas asked whether there had been any research into the time problems in ESATAN. O. Pin said that a lot of the time could be accounted for in the VARIABLES1 block handling. This had been discovered during the work with CNES into the FHTS solvers. Initially it was thought that the new solver routines were the source of the problem, but the time was actually taken in the service routines which are used to check the various properties. What was true for the FHTS solver probably applied to a certain extent to the ESATAN solvers.

C. Williamson said that ESATAN loses when using small models because of the additional overhead involved in pre-processing the model and generating and compiling the Fortran.

1.4. Improving Ray-Tracing Algorithms for Monte-Carlo Simulations.

B. Shaughnessy (RAL) presented some ideas on using discrete probability functions to

determine the path of rays after multi-reflections. (See Appendix D)

HP. de Koning (ESTEC) asked whether B. Shaughnessy was aware of the extended view factors in ESARAD. These had certain similarities to the presentation in that they combined incident and specular behaviour. B. Shaughnessy had looked into using the Markov chain of transition probabilities and matrix algebra.

P. Renard (Astrium-SAS) asked whether the accuracy of the results was dependant on the meshing. B. Shaughnessy said that it was, but noted that so far he had only studied simple geometries. He didn't yet know whether the algorithm would scale to handle more complex geometries. If it didn't work with more complex geometries, then he would be forced to drop this approach.

1.5. New Ray-Tracing Technique for THERMICA

M. Jacquiau (Astrium-SAS) described improvements to the ray-tracing used in THERMICA to make use of oct-trees and other techniques. (See Appendix E)

HP. de Koning (ESTEC) asked whether the oct-tree algorithm started with a cube or with a rectangular block. M. Jacquiau answered that they used a rectangular block, and used voxels of the same ratio.

F. du Laurens (Alstom) wondered about how well the model was encapsulated in the voxel space. He asked about the voxel breakdown for an unmeshed sphere. M. Jacquiau said that at the surface of the sphere there would be a lot of small voxels. During initialization the sphere would be meshed, but voxels were only required for the surface. It was possible to tune the initial meshing.

O. Pin (ESTEC) asked about the number of levels of voxels in the oct-tree. M. Jacquiau said that the oct-tree typically went down to between 6 and 8 levels, but for pathological cases the oct-tree could have more levels, even 20. However, it wasn't usually possible to have too many levels for the whole model, so more levels were only usually used for specific small areas such as electronic equipment. O. Pin asked about the criteria which were used. When there were empty voxels? How was it possible to stop the increase in levels? M. Jacquiau said that the recursion usually stopped when the voxel was empty, but it was also possible to limit the levels by stopping when there were just 2 or 3 surfaces in the voxel.

1.6. Report on TFAWS and Introduction to ThermPlot

HP. de Koning (ESTEC) described the TFAWS workshop and highlighted the interesting developments. He went on to describe ThermPlot, a utility written by Hume Peabody of Swales, and presented at TFAWS. (See Appendix F)

B. Shaughnessy (RAL) asked about the maximum size of ESATAN file which could be handled by ThermPlot. O. Pin (ESTEC) said that he had been able to process a 16Mb ESATAN output file for METOP corresponding to a transient case. HP. de Koning said that the model contained

about 1200 nodes.

O. Pin admitted that processing the ESATAN output files did take time. It was usually better to work with binary data files rather than parsing ASCII files. He said that it took 3 hours to process the ESATAN output file for METOP in order to obtain the heat balances. This was on a system with a 400 MHz Pentium 3 processor with 128 Mb of memory. M. Molina (Carlo Gavazzi Space) asked how big the ESATAN output and Excel files had been. O. Pin said that the ESATAN output file for this particular METOP model was 16Mb. This file contained heat balance data rather than temperature data. The Excel file produced from this by ThermPlot was 10Mb. However the size of the files would vary on a case by case basis. If the user created a large number of plots, or a plot involving a large number of nodes, then the resulting Excel file could become much larger.

O. Pin asked whether anyone would be interested in using ThermPlot. It was a free tool, and could be downloaded from the Swales Web site. This was a first but still limited answer to the recurrent need for a post-processing tool. He said that Hume Peabody was very enthusiastic, and was very responsive to problem reports. He stressed that the ESATAN side of ThermPlot was still in being tested. E. Cosson (EADS) and two others said that they were interested. O. Pin said that in any event, various people at ESTEC would experiment in using ThermPlot.

K. Caire (Alcatel) asked whether ThermPlot also had an interface for TMG. HP. de Koning said Hume Peabody was working on providing a TMG interface, but he was working single-handed. HP. de Koning said that ThermPlot was a nice initiative, but it depended on a single person. The software was free, but there were also no guarantees about its future.

2. Tuesday 9th October: Afternoon Session

2.1. Artifis/Topic/ThermXL

F. du Laurens (Alstom) described the use of three light weight tools for early design studies, and demonstrated Artifis and Topic. He said he would demonstrate ThermXL after the session to anyone interested. (See Appendix G)

O. Pin (ESTEC) asked whether anyone had used the version of Artifis that had been included on the ESARAD 4.2 CD. A. Robson (Astrium-UK) said that he had tested it, but had not actually used it. He agreed that it was very quick.

J. Persson (ESTEC) asked whether it would be possible to extend the Topic demonstration to use the STK file as input. F. du Laurens said that he didn't have STK installed on the PC, but it would be possible to use the STK compatible file which had been generated during the previous run of Topic. All that was needed was to remove the initial comment line from the file.

O. Pin asked whether the data could be easily imported into Excel. F. du Laurens said that it was possible, and users could also create an Excel macro to extract data.

O. Pin said that Artifis and Topic had been distributed on the ESARAD 4.2 CDROM, and asked how people could access the tools now. F. du Laurens said that it would be possible to include them with the next version of ESARAD, if there was sufficient demand, and if it was OK with ESA. It might then be possible to incorporate D.Gibson's speed improvements.

P. van Leijenhorst (Fokker Space) noted that the user could see the percentage of eclipse per orbit, but asked whether it was possible to see the complete duration of eclipse during the whole mission. F. du Laurens said that the user would currently need to set the mission time step to be the same as the orbital period, and then sum the relevant columns of data in a tool such as Excel.

K.Caire (Alcatel) was interested in the Low Earth Orbit capabilities, and specifically wanted to compute the orbital drift. F. du Laurens said that Topic could handle J2 perturbations to the standard Keplerian orbits, so the orbit precession could be taken into account.

T.Basset (Alcatel) asked whether Artifis and Topic handled yaw steering in the attitude control. F. du Laurens said that Artifis and Topic used the so-called "Euler angles" just as in ESARAD 3.2. The user had to fix the attitude at the start of the run using these Euler angles. HP. de Koning (ESTEC) said that it wasn't currently possible to do yaw steering. The user could not change the attitude of the geometry within an orbit. This could be one possible extension of the tools.

The discussion went on to the presentation of ThermXL by H. Brouquet (Alstom).

O. Pin said that in the new version of ThermXL the user could call the solvers from Visual Basic, so it was now possible to do parameter runs by using Visual Basic to generate the parameters and then call the solvers. O. Pin stressed that any model which had been built in ThermXL 1.0 would still be valid in ThermXL 2.0.

V. Perotto (Alenia) remarked that ThermXL could calculate the heat flux for each node, and asked whether it was also possible to calculate the sink temperature. O. Pin said that this was a good idea in principle, but asked what V. Perotto meant by sink temperature. The question of sink temperatures had been raised at previous workshops, but there had never been complete agreement on the definition.

O. Pin said that there had been a demo version of ThermXL 1.0 which allowed a maximum of 21 nodes. ThermXL 2.0 would probably be released in a commercial version only, with no demo version, but it would only cost 1000 euros (i.e. 2 days of engineer time).

2.2. Stochastic Approach to Spacecraft Thermal Control Subsystem

F. Lamela (CASA) described a stochastic method of performing thermal analysis, to identify the critical parameters in a spacecraft thermal design, for example. (See Appendix H)

C. Williamson (Eutelsat) asked about the calculation of the variation of parameters for MLI. F. Lamela said that in order to decide the interval for the normal distribution used for the parameters, it was necessary to negotiate with the designers of the other parts if possible, but there was not really any distribution law which could be applied to satellite components. For the

MLI they had used a normal distribution. For dependant variables, the software would accept any formula, so the user could specify a logarithmic law for example, but user was free to use a normal distribution, or whatever made sense. The software offered a “calculator” panel to allow the user to input the formula used to calculate the variable dependency. He stressed that user often had to push to get information about the other subsystems to use as input.

C. Williamson asked how the stochastic approach affected systematic errors. F. Lamela said that the user did not need to assume that there would be systematic errors. The software used Monte Carlo methods and the sampling used a combination of data. C. Williamson asked about pure calculation errors. F. Lamela said that they had run 100 Thermica and ESATAN model cases.

S. Kasper (Jena-Optronik) asked how the ESARAD results had been exported into ESATAN. In running parametric cases there was a need to perform a lot of runs without manual intervention, so some sort of batch file was required. F. Lamela said that it had been difficult in ESARAD, but Thermica allowed the user to add a copy command to get the data into the ESATAN file. S. Kasper commented that it was often necessary to have additional small programs to manage parameter data.

HP. de Koning (ESTEC) asked how much CPU time and power had been needed for the battery analysis. F. Lamela said that the CPU time for the overall analysis was the CPU time for one run multiplied by the number of runs, therefore the user needed to find ways of reducing the time per run. One way was to add a subroutine to the ESATAN model to read the parameters each time, rather than pre-processing the whole model with a new set of parameters. Using some READ statements could save a lot of time. HP. de Koning asked how long the analysis had taken. F. Lamela said that the basic analysis had taken one hour for the MiniSat case, but the stochastic approach had needed only 24 hours for 80 cases.

HP. de Koning asked whether the software ran on a Linux cluster. F. Lamela said that the software only ran on one CPU, but some clever scripting was needed to send the ESATAN runs to other machines.

C. Puillet (CNES) asked how it was possible to know the confidence interval for the results without knowing the distribution law for the parameters. F. Lamela said that by using a probability density function on the results, it was possible to order the temperatures and accumulate cases. When 95% of them matched, the user knew that the results have been achieved.

O. Pin (ESTEC) announced that ESA intended to open an ITT on the subject.

2.3. ESARAD

F. du Laurens (Alstom) presented details of various assumptions used in ESARAD, and tips and useful pieces of information which could be used to improve the users’ modelling capabilities. (See Appendix I)

H.Rathjen (Astrium-D) asked why the user couldn’t put the capacitance values in the

VARIABLES1 block so that they could be used to define temperature dependencies. O. Pin (ESTEC) answered that this was possible, and the user could do it using cut and paste editing.

S. Kasper (Jena-Optronik) commented that when the cutting facilities are used, sometimes ESARAD is unable to calculate the capacitances. F. du Laurens said that the capacitance calculation should work, even for cut surfaces. If S. Kasper had a model with this specific problem he should forward it to user support for investigation.

S. Appel (ESTEC) asked whether the thickness parameter affected the outer surface of a shell. F. du Laurens said that ESARAD worked with thin shell geometries, so the thickness is only a notional value which gives a means of calculating the mass of the shell and doesn't affect the geometry as such.

S. Appel asked whether there was any limitation in the value of NBDIV which the user could specify, because there was no mention of this in the manual. F. du Laurens said that he was not sure, and would need to check. P. Renard (Astrium-SAS) said that NBDIV was used by the planet flux calculations, in a different parser. NBDIV was not the same thing as the box meshing. In Thermica, NBDIV was not a user parameter.

P. Renard had a question about the projection of the Sun onto the bounding box in the case of non-parallel solar flux. The circle representing the projection of the Sun on the enclosing box was very small. This implied that NBDIV would have to be large. F. du Laurens said that normally the user left the NBDIV parameter set to zero. In this case, ESARAD would calculate the optimal value for NBDIV.

B. Shaughnessy (RAL) asked whether the intersection test between the ray from the spacecraft to the planet, or the sun, was with the edge of the bounding box or with the voxels. F. du Laurens said that the test was made with the projection on the bounding box.

HP. de Koning (ESTEC) said that there was a publicly available ESARAD algorithms document which explained all of the calculations. This document had been supplied with ESARAD 3.2, but was still valid, and could be made available to users.

S. Kasper asked about the exp3to2 utility. Where could he find it? F. du Laurens replied that it was only relevant to the PC version of ESARAD, and could be found in the ESARAD_DIR\bin directory of a PC installation.

I. Renouf (Astrium-UK) mentioned that he had experienced problems with importing GFF files into ESARAD. S. Kasper said that he had used this, but wondered whether it was possible to have more than 8 colours for displaying the results. F. du Laurens said he was aware of this. The user had to click on the colour selection dialog box. The default number of colours was 8, but the user could select up to 16 if needed.

HP. de Koning warned everyone that under Windows NT, there was an inherent limit of 2GB maximum memory which could be used by any particular process (as opposed to most Unix platforms which provide up to 4Gb memory per process). Therefore, if the model was very large, or there were many orbit positions, it was possible to get past this memory limitation by using the batch processes. This released the memory which would otherwise be used by the

GUI.

S. Appel said that when running batch versions of a model, it was often convenient to be able to run several versions of the same model, each with slightly different parameters. This could be achieved by resetting the \$HOME variable to point to the current directory so that different versions of the model could be run in parallel in different directories.

A. Robson (Astrium-UK) commented that ESARAD generated a single ESATAN file and that this often needed to be split up further in order to include the different blocks in a master skeleton ESATAN file. He wondered whether there was any way of automating this. F. du Laurens said that one problem with this was that ESARAD didn't know about ESATAN sub-models. HP. de Koning acknowledged the problem and added that the next release of ESARAD would allow the user to define an ESATAN template file containing place-holders for the blocks of interest. The ESATAN file formatting would then insert the blocks at the appropriate places. This feature should be in the next major release.

F. du Laurens said that he would be talking about the up-coming releases in a presentation on the following day.

2.4. Round Table Discussion

HP. de Koning (ESTEC) introduced the last part of the day, which was a Round Table Discussion (even if the table wasn't really round). He told everyone that O. Pin (ESTEC) had sent out a questionnaire with a space to indicate subjects for discussion. ESTEC had scanned these replies for common topics. He showed "bullet-lists" of the main points. (See Appendix J)

2.5.1. Model reduction

The first common topic was "model reduction".

HP. de Koning asked why people felt that model reduction was important. Was it for reasons of computing time? Or to simplify post-processing of results? Or for the integration of models from sub-contractors.

J. Persson (ESTEC) answered that for the International Space Station analysis there was an obvious need to have reduced interface models otherwise the analysis would be completely unmanageable. This was an example of a reduced model being made available from the system level for the sub-system or payload level analysis.

S. Price (Astrium-UK) said that the integration of sub-contractors' models into an overall satellite model was the main reason in Astrium-UK. O. Pin thought that integrating large numbers of detailed and reduced models would also be difficult to manage. S. Price admitted that these resulted in very large models.

O. Pin asked whether they would have the same approach if the thermal software tools could handle models of 10000 nodes.

S. Price said that the CPU time was also an important factor. For a satellite such as Rosetta with 20 instrument sub-models, if each sub-model was allowed to have 1000 nodes then the overall model would be too large. There was the question of CPU time, as well as the physical capabilities of ESATAN and ESARAD.

J. Persson felt that the use of reduced models was a system integration issue: each module developer was not interested in the details of the other modules.

HP. de Koning agreed that there were actually two kinds of reduced model usage: the top-down interface specification approach needed in phases A and B and the bottom-up approach needed in the phase C/D verification of interfaces, etc.

F. Lamela (CASA) asked what was the real meaning behind model reduction. If there is an interface for a prime contractor, what were the main parameters for the model. The supplier of the platform was only interested in the overall heat flux. Why was it necessary to supply a model to specify single heat fluxes? The reduced model could be as simple as a table of fluxes, or temperatures of key points, and need only contain 20 values. S. Price said that it really depended on how many instruments existed in the model. There was also the issue of whether the integrator was also the supplier of the non-thermal side as well. It wasn't sufficient to simply define the interface in terms of temperatures or fluxes because often the complete geometry model was needed too, for thermal-radiation interaction. HP. de Koning agreed that if the interface was limited to a conductive mounting plate only, then just supplying temperatures or fluxes was fine, but if there were radiative links then something more was required.

F. Lamela said that models often contained 100 to 200 nodes to model internal nodes which were not needed for the external interface. There was a difference in the quality of the models required internally and that needed by the prime contractor. S. Price argued that the prime contractor also needed the internal interaction in order to get the heat flows from the instrument into the spacecraft. F. Lamela admitted that the final decision was the responsibility of the prime contractor and that they might need the whole model. S. Price said that the detailed design was done by the instrument sub-contractors, but they still needed realistic flight conditions at the spacecraft level. The prime contractor needed geometrical models, and not just the interface temperatures. He stressed that what was required was a representative model, and that this didn't necessarily have to be a detailed model.

F. Lamela said that a condensed model gave information on the temperatures of 15 or so elements. When there was a small problem, the temperatures could be extrapolated from these elements. This was how it had been done 20 years ago by the structures people. A model was needed for the interfaces. A condensed mathematical model could be used for extrapolation in the whole model. S. Price felt that a condensed model only reflected a limited number of parameters, and that they were only valid for certain conditions. F. Lamela said that the models should contain independent parameters only. HP. de Koning said that the main parameters were usually represented. S. Price said this gave a reduced model which the prime could use but it was still better to take the detailed model in order to remove an errors introduced by the model reduction, provided the software could handle the complete detailed model HP. de Koning said the prime contractor could keep on running the complete model, but there were problems with configuration control and integration.

O. Pin felt that there was a problem of feasibility in using the detailed models. There were two options which needed to be considered for future developments. In the first case where users needed to work with the complete models, the tools had to be scalable to handle the large models. In the second case where users needed to work with reduced models, the tools would need to support model reduction or help to automate it.

HP. de Koning said that the thermal tools needed to be adapted to handle large models in order to make the complete model approach feasible. The question of model reduction always generated lots of discussion. There was also the problem that serious verification of the reduced model against the detailed model was often very difficult, and sometimes impossible. Everyone needed to have confidence in the results.

S. Price said that Astrium-UK had specifications of how to define models and the relationships between detailed and reduced models, even though using reduced models could introduce errors.

HP. de Koning felt that model reduction was enough of a problem that verification of any model reduction tools was necessary. These were often a black box with some matrix linking input to output.

S. Price felt that most large projects had specifications for model reduction, and most had some software to help do it. He was concerned about trying to analyse conditions for which no correlation data was available, because often there was no way to ask a sub-contractor for the data years after the original work had been completed. To investigate such cases an analysis run for Envisat would take 24 to 36 hours even with the reduced instrument models.

O. Pin said it looked as though model reduction was something that everyone would have to live with, but he asked whether there was a standard way of doing it. Should ESA address this? Should there be studies into automatic model reduction functions? The question would then be how to compare the different model reduction schemes. He felt that in the end it would all come down to engineering judgement.

S. Price said that Astrium-UK had been involved in Rosetta, Envisat and Metop. A common approach had been developed within Astrium on how to provide models to other groups within Astrium. This approach would also need to look at reduced models.

C. Williamson (Eutelsat) felt that there was not one correct answer when it came to model reduction. The model reduction required for one instrument might not be the same as required by another instrument. The prime contractors needed to have a pragmatic approach.

HP. de Koning summarized the discussion so far:

- for the foreseeable future everyone would have to live with reduced models. For example, the ISS environment specifications had to be top-down, but allow a bottom-up approach for integration.
- in addition to the ECSS standard for thermal control, there was a need to have checklist for model reduction in order to standardise the procedures used.
- project specifications could then refer to this checklist and guide the discussions towards a

common approach.

HP. de Koning informed everyone that W. Supper (ESTEC) would give a short talk about the ECSS Thermal Standard. He felt that the level 2 documents could focus on such thermal analysis issues. O. Pin asked whether anyone would be interested in taking part in the ECSS Working Group.

C. Puillet (CNES) said that model reduction had been discussed in previous round table sessions and that a lot could be achieved by specifying a sink temperature. O. Pin said that the Thermal Control Standard did provide one definition, but not everyone was agreed on this definition. He went on to say that the Thermal Control Standard could also provide modelling and model reduction guidelines. He felt that this was an issue because people often needed to work with someone else's models. He said that he had been called in to help with problems in ESATAN models where the model reduction had been a real mess.

P. van Leijenhorst (Fokker Space) remarked that if you didn't trust the model, or were doing shadow engineering, then this needed a different approach to working with an interface model. When dealing with an interface model, it could be treated as a black box and you didn't need to care about the internals. If you needed the model for shadow engineering then you needed to be able to understand the model.

A. Aguilar (SpaceContact) asked whether it was possible to have a combined interface between models in order to allow several sub-modellers working in parallel. O. Pin replied that if we took ESATAN as an example, which allowed the user access to the Fortran, it would be necessary to have message-passing between the different sub-model parts. HP. de Koning admitted that, technically speaking, such model coupling was possible: it would require the addition of very clean inter-process communication to ESATAN. However, he felt that it would not solve the problem of managing a multitude of models, and there would still be problems in integrating models.

K.Caire (Alcatel) said that every thermal mathematical model which she worked on always resulted in a reduced model. Everyone knew that the reduced model is not a true physical model, but it could be used for random parameter variations. You don't always have enough information about the heat flow in the reduced model and it was difficult to correlate. GAETAN could do it, but it was not complete. She said that the main criterion was the heat balance. HP. de Koning agreed that to verify that a reduced model represents the detailed model the heat balances should be similar.

O. Pin once more asked whether there were any volunteers to work on the ECSS standards.

F. Koorevaar (Fokker Space) asked about NASA standards. O. Pin said that there was a NASA handbook from Marshall Space Flight Center, but this was not available to everyone.

S. Price said that Astrium had a working group which was trying to tackle these issues.

V. Perotto (Alenia) said that he was a little puzzled about the usefulness of model reduction. He had been involved in cases where model reduction had been tried, but they had ended up in using the detailed models anyway because it was less work to use the detailed models than to

prove that the detailed and reduced models were equivalent. When you need to use a reduced model from elsewhere, it was always necessary to identify the requirements as to why the reduced model had been produced. If these were not well defined then you can have a reduced model that is difficult to correlate to the complex model. Often you end up reducing the complex model again, and this couldn't be done automatically. There was some need for support in the post-processing of models. However it was important not to lose any visibility in the model, especially if there was a need to use the model again at some point in the future.

HP. de Koning asked whether automatic model reduction was only realistic for interface models. He felt that humans needed meaningful numbers in the model.

2.6.2. Cryogenic Systems

The second issue which had been identified from the questionnaires concerned cryogenic systems, and HP. de Koning asked about the specific issues which needed to be discussed.

B. Shaughnessy (RAL) said that RAL had a number of projects involving cryogenic systems. There were problems of getting models to converge in various cold stages, or in the cool-down stages.

S. Price answered that on the Astrium projects involving cryo-coolers they used their own logic and software rather than using ESATAN solvers directly.

HP. de Koning said that for Herschel-Planck there was one sensor which needed to be kept at 0.1K. There was a heat balance which was very sensitive to small changes in the heat flux, and this sensor was not far from a unit with an 800W dissipation. The model was very ill conditioned.

HP. de Koning asked whether anyone had any more specific issues relating to cryogenic modelling.

I. Renouf remarked that as the systems became cooler. the conductivities of the materials also went down. This often means that the meshing needed to be changed for the lower temperatures because if the nodes were too big then the results were too optimistic.

F. Lamela said that achieving convergence in some cases was sometimes difficult, and to overcome this they used transient runs over 5000 seconds instead of a simple steady state calculation. O. Pin agreed that this was one way of doing it, and in fact the same strategy of obtaining a steady state by time marching was used in fluid systems and with heat pipes.

F. Lamela said that even when using the same software the solution was highly dependent on the actual conductors. It was possible to reach a solution with virtually no heat imbalance, but if a single high conductance was suppressed the results could be different. It was possible to reach a solution where the heat balance was perfect but adding or removing a single node could make a difference of 20 degrees in the results. This made it difficult to perform correlation or sensitivity analysis.

S. Price said that the Astrium cryogenic solver took this into account. O. Pin asked whether it used a time-marching or a SOLVIT type approach. S. Price answered that it used steady state iterations and that the number of nodes made a big difference as the conductivity changed. This was important for example on a strap which had a different conductivity at each end because of the temperature difference. He asked what assumptions were made in the ESATAN equations for the steady state solvers which were not valid for cryogenic analysis. HP. de Koning added that for transient analysis using SLFWBK the \$VARIABLES1 block was only called once, at the start of each time step, and this meant that the values were often out of date as far as cryogenic processes were concerned.

P. Renard (Astrum-SAS) commented that when using ESARAD or THERMICA for very cold parts of the model, the use of the extinction parameter in the ray tracing could make a big difference. In THERMICA this was normally set to 1%. This was usually acceptable for normal temperature ranges, but not for cryogenic conditions. The user needed to set the extinction threshold to a low value and specify more rays to improve the accuracy.

2.7.3. CAD and FEA Software

The next issue thrown up by the questionnaires related to the use of CAD and FEA software. HP. de Koning asked whether people needed to use it on a routine or an occasional basis.

P. van Leijenhorst said that he had only needed to use it once in 11 years. V. Perotto said that Alenia didn't use it.

K.Caire said that Alcatel had missions which involved the use of CATIA. They tried to use CATIA surfaces, but were always obliged to construct another model for conversion to THERMICA for use in the thermal analysis. HP. de Koning said that they could use the idealisation of the CAD model within the CAD tool to give a simplified geometrical model. E. Cosson (EADS) said that they had the same approach using IDEAS, and converted the geometrical mathematical model to THERMICA. HP. de Koning asked why they didn't use IDEAS/TMG and was told that they hadn't used it for the thermal side for a long time.

JP. Dudon (Alcatel) said that Alcatel had a problem with a tool which handled the connections between CORATHERM and a CAD tool. They were currently sub-contracting some extensions to OPEN/CASCADE in order to be compatible with new requirements. HP. de Koning asked whether the idealisation was being done manually or automatically within the tools. JP. Dudon replied that they were still at the first step of the development and were working on creating all of the geometries in the tool. The second phase would be to import the geometries from the CAD tool and then simplify them. O. Pin wanted clarification that the idea was to use the CAD tool. He wondered what had happened to CIGAL. JP. Dudon said that they had used CIGAL in the past, but were looking at a period when both CIGAL and the CIGAL-compatible new tool could be used, but after certain point only the new tool would be used.

A. Aguilar commented that there had been a presentation about introducing NURBS into ESARAD at the previous workshop. He felt that this would solve the problem to some extent.

HP. de Koning explained that there had been a study into converting STEP AP203 geometry

into ESARAD and using NURBS for ray-tracing. The study had almost been finalized and had resulted in a functionally working product. However, it was computationally very expensive, so it wasn't obvious whether it would be usable in its current form. It wasn't clear whether the best approach would involve using the NURBS directly or whether the NURBS would be handled using facets. He noted that there were other areas which could be investigated, such as the oct-tree implementation used in TSS and also presented by Astrium-F, but there wasn't an easy solution to handling large models. Good meshing algorithms were available in Finite Element tools, so no new development was really necessary there, but new algorithms would be needed in the thermal tools. However it would be the interface which would be delivered. For example, it would be possible to input CATIA models into ESARAD. If NURBS were used for the primitive shapes, then it would be possible to recognise these and simplify them to the primitive shapes rather than continuing to treat them as NURBS. HP. de Koning asked whether anyone had any experience in exporting models or results back into the CAD/FEA tools.

C. Williamson said that he had never had to do this for the design phase, but had needed suppliers' temperature maps in the CAD model. This would be the real application of an export capability.

2.8.4. Post-processing

The final issue which had been selected from the questionnaires related to generic post-processing.

HP. de Koning said that there were a lot of issues concerning post-processing, and trying to find budget and resources to duplicate what was already available in commercial off-the-shelf (COTS) packages would be very difficult.

F. Lamela said that as far as CASA was concerned this was an issue which could be ignored. ESATAN needed to calculate temperatures, and it needed to do it well. Other tools could be used to perform other functions. It was always possible to generate post-processing software to use the ESATAN results and ESARAD geometry information. However this would present problems later because each company had different needs. This was also true within companies. An antenna analysis had one set of requirements, a complete satellite analysis had different requirements, etc.

HP. de Koning stressed that there was a need to get away from monolithic applications which did everything. If there was a set of standard data files, then it would be possible to develop suites of tools which made use of the standard format. He felt that it would be better to have Unix-type filter tools to do the post-processing of these standard files.

F. Lamela said that as far as the post-processing for the structural people was concerned, they didn't always know what they wanted, or the models were not fully compatible, or there was a need to interpolate results in bracket assemblies, etc. Allowing a general formula was a little dangerous. One important area was the visualisation of results.

A. Aguilar commented that it would be interesting to allow the user to have some template functions so that the user could select the format and content of output, to have tab separated

output, or spaces, or whatever, in order to allow the integration with in-house or COTS software. He felt the user should be allowed to define the output format.

HP. de Koning said that the HDF5 binary data format had complete C and F77 application programmer interfaces to enable users to read the data. This was one approach. Another widely recognised format was the use of comma separated variable lists. He felt that there should a small number of simple, straight-forward formats, or space-efficient formats, and that should be all that the tools should support. He would hesitate about developing specific formats, because there would always be someone with a new requirement.

V. Perotto said that the post-processing information was interesting, but felt that the users would be able to do a lot more for themselves if a clear explanation of ESATAN's COMMON blocks were made available. Everyone had been obliged to experiment with the COMMON blocks if they wanted to extend the output for post-processing. He asked why this information had never been made available. HP. de Koning admitted that many people had reverse-engineered this information so that they could use it for their own tools. Maybe it would be possible to create a feature request for the supply of the COMMON block specification. The original reason for not disclosing the format had been to allow Alstom the flexibility to change the implementation of the software and COMMON blocks without affecting the users.

A. Aguilar said that Alstom should produce some APIs to allow retrieval of data from the COMMON blocks. HP. de Koning repeated that HDF5 had such APIs. He stressed that direct access to the COMMON blocks endangered the portability of the software and models between partners, or with SINDA, and could make shadow engineering difficult. What was needed was a simple call in the \$OUTPUT block to dump data into a standard format.

P. Renard said that he had some experience of converting an ESATAN model to SINDA for a customer. He warned that using knowledge of the ESATAN COMMON blocks within MORTRAN subroutines made it harder to convert the model to SINDA. HP. de Koning agreed that the more MORTRAN there was in a model, the more likely it was that there would be problems in model portability with SINDA, etc. If models needed to be ported, then maximum portability could only be achieved if only the standard features of the software were used.

3. Wednesday 10th October: Morning Session

3.1. Temperature Control Loop Analyzer (TeCLA) Software

V. Perotto (Alenia) described work done by his colleague F.Burzagli on the TeCLA software. (See Appendix K)

M. Molina (Carlo Gavazzi Space) noted that the software worked for single phase loops, and asked how much effort would be needed to handle two phase loops. V. Perotto said that Alenia did not have any two phase loops in their part of the ISS work, so there had been no need to provide a two phase capability.

O. Pin (ESTEC) asked whether it would be difficult to provide a two phase capability. V. Perotto said that it would be necessary to find the correct transfer functions. The control interface with the loop was not usually done on the branches which had two phase flow. These were normally only single phase. Adding the control interface which truly reflected the physics of the loop could greatly increase the complexity of the model. M. Molina summarised by saying that the physics of the loop was changing in one place, but the control was actually handled elsewhere. V. Perotto said this was the case, and changes to the model would need to reflect the physics.

O. Pin remarked that, at ICES, V. Perotto had mentioned the use of EcosimPro to handle the control laws, and wondered whether they had thought about using it. V. Perotto confirmed that they had tried EcosimPro, but had only used in the same way as they used ESATAN/FHTS or FLUINT, so this was not really different. They needed to run lots of cases with changed parameters, and spend a lot of effort for multiple parametric runs. O. Pin said that it was possible to create components to handle this, but it was still necessary to identify all of the control coefficients. He added that functionality was available in EcosimPro to identify the control parameters. V. Perotto agreed. It was necessary to identify the control coefficients in advance to be able to perform parametric studies.

3.2. Analysis of Spacecraft Thermal Stability

B. Shaughnessy (RAL) presented some ideas on the start of a project to determine the stability of spacecraft thermal design and analysis. (See Appendix L)

HP. de Koning said that if ESARAD was used for the prediction [it was], then ESARAD used double precision throughout, but the transfer to ESATAN via an ASCII file caused truncation. There was some work in progress to look at a full binary transfer process in order to preserve the accuracy of results.

HP. de Koning asked whether the trade-off between lumped parameters and finite difference and finite element methods had been considered. He felt that finite element methods might provide a better representation. B. Shaughnessy said that the lumped parameter approach was better for representing spacecraft. The different projects at RAL used ESATAN, so this investigation into the analysis methods was to validate the original work. If the investigation disproves the accuracy of the results, there would be a need to look again at the methods being used. HP. de Koning said that it would be possible to use hybrid systems, with finite element analysis for the optical instruments and ESATAN for the rest of the spacecraft. B. Shaughnessy said that the results had to be mapped to the structural finite element models eventually anyway, and that would be another area where errors could be introduced. With more methods the requirements became less well defined.

V. Perotto (Alenia) asked whether it was possible to use the standard tools for analysis such as ESATAN, ESARAD and finite element methods. He wondered whether an analytical simulation might be better, or a combination of using the standard tools down to a certain level and then use values from that level as boundary conditions or input to the next layer of analytical tools. Perturbations could be calculated using Fourier transformations. B. Shaughnessy felt that it was a good suggestion to couple finite difference methods with something else.

C. Williamson (Eutelsat) remarked that there would always be uncertainty in the data. In the example given during the presentation, there were uncertainties in the temperature gradients within the sphere. He felt that conductivity and capacity values were also needed.

G. Barbagallo (ESTEC) commented that the thermal requirements had been expressed in terms of the spectral power density at a certain frequency. He asked about the thermal fluctuation which needed to be predicted. B. Shaughnessy said that the temperature variation was a peak to peak difference of 2.0×10^{-6} kelvin at room temperature. G. Barbagallo agreed and said that this would give 10^{-11} kelvin per root hertz at certain frequencies. There was the need to divide by the bandwidth. He wondered how the 10^{-4} figure had been obtained. B. Shaughnessy said that this number had been specified in the structural analysis report. G. Barbagallo remarked that ESATAN had not been designed for such a small variation. HP. de Koning said it was a question of whether the user could live with the convergence criteria. It might be necessary to look at the heat balance rather than the temperature differences. O. Pin (ESTEC) said that this area of ESATAN was currently being investigated, but he was sceptical of whether this would really help for such requirements. HP. de Koning said that normal double precision was accurate down to 10^{-13} , and offered 13 significant digits, so the analysis needed accuracy which was already quite close to the limits of what was achievable.

V. Perotto said that if a solver could be upgraded to support convergence on the heat balance, it would also be interesting to work with the energy, which was the integration with respect to time.

C. Williamson commented that this accuracy was required during Phase A. Thinking ahead though, if the hardware was actually built during Phase B or C, how could it ever be validated? B. Shaughnessy said that verification would be someone else's task. F. Lamela (CASA) said that it would be possible to measure it optically using the laser in the instrument. HP. de Koning agreed that the instrument itself could be used in the verification. It was clear though, that to ensure the spacecraft worked, it needed to be simulated with a high degree of accuracy.

3.3. An Overview of Bepi-Colombo Thermal Analysis

I. Renouf (Astrium-UK) gave an overview of the Bepi-Colombo mission and the challenges for the thermal design to handle the wide range of thermal environments for the different phases of flight, as well as the orbit and landing on Mercury. (See Appendix M)

F. du Laurens (Alstom) asked whether I. Renouf would be interested in wider planetary modelling in ESARAD at some time in the future, or a hyperbolic orbit capability for modelling the Venus fly-by. I. Renouf said he would be interested, and said that they could discuss it after the presentation. It would certainly be relevant for the thermal analysis. The design for the fly-by behind Venus was important because of the need to keep the spacecraft warm. F. du Laurens asked whether I. Renouf had used his own routines for planetary modelling. I. Renouf replied that he used in-house routines for varying the temperature. F. du Laurens asked whether this temperature was based on the sub-satellite point, or used the field of view of the planet. I. Renouf said that it used the average value.

C. Williamson (Eutelsat) commented that he had also tried doing something, but it was not

elegant. He had used Thermica with different planet temperatures held in arrays, with some logic to select different temperatures from the array at various points around the orbit. These arrays had to be generated in advance, and added to the ESATAN model as well.

I. Renouf said that the main problems in the design and analysis had to do with the scale an variation in the flux values for the different phases of the flight and within the final orbit. At the closest point to Mercury, the altitude was 400km with flux values above 10000W/m^2 . The variation of the flux around the orbit was also very rapid. He was concerned about the scaling effects.

3.4. ECSS Initiative

W. Supper (ESTEC) gave an impromptu explanation of the ECSS standards work, and described some of the results so far. He said that everyone should remember the home page for the ECSS standards in order to download the existing standards. These standards could be downloaded for free. There as a lot of information on management aspects, product assurance, quality assurance and various technical areas. For Thermal Control, the level 2 documents already existed, and there were on-going activities to define level 3. He had a limited number of old news letters which people could take away with them, but anyone could download electronic versions of the latest news letters from the web site. He stressed that the process needed input from, and co-operation of different teams from the space industry with Europe rather than just from ESA.

The web address was <http://www.estec.esa.int/ecss>

O. Pin (ESTEC) emphasized that volunteers were required to help with this work. HP. de Koning (ESTEC) said that EuroSpace were helping to co-ordinate the work of all of the different space contractors. EuroSpace would pay for the travel and subsistence of those contractors who participated in ECSS meetings, so not all of the costs had to be borne by industry directly.

W. Supper said that the high level Thermal Control standard, level 2, had already been issued, although there were some errors which needed to be corrected. Three level 3 documents where foreseen:

- thermal handbook (one version had been developed for CDROM, but this would need reworking to be a paper-based document)
- reference data (solar constants, etc. so that everyone worked with a common set of data)
- guidelines for analysis (a cookbook containing working practices)

The more people who were involved in providing input, the better the acceptance level across European space industry. This was better than a small group developing a standard to be imposed on everyone else.

3.5. Application of CORATHERM for Spacecraft Thermo-Elastic Analysis

JP. Dudon (Alcatel) described the current state of CORATHERM, and the recent developments of the tool to improve its use in the thermo-elastic analysis of spacecraft. (See Appendix N)

S. Appel (ESTEC) was interested in hearing more about the method used to transfer temperatures from the thermal nodes to the finite element nodes. JP. Dudon said that the software made use of the partial nodes used in the EQUIVAL method. These gave local temperature information on structural panels, or the power on unit nodes. Then it was possible to use the recalculation process to transfer the temperatures from the automatically created partial nodes onto the classical thermal model. Points could be created on the finite element mesh which matched these nodes.

S. Appel asked whether this was a consistent method. JP. Dudon said that it was difficult to discuss the method without needing to go into more detail than could be given in such a short presentation. The engineers at Cannes had found that combining the radiative and conductive aspects of panels gave a better way for the conductor processing, and allowed the possibility of having local information about the geometry and the interpolation of values between points. O. Pin (ESTEC) said that in EQUIVAL the panels were meshed finely, and then star delta transformations were applied to the mesh to reduce it, taking environmental conditions into account.

JP. Dudon gave an example of a panel which was cut into element nodes. The conductive and radiative links of the nodes were calculated. Some nodes could be eliminated and some combined to give classical thermal nodes. The thermal nodes have the averaged temperatures of the partial nodes which have been eliminated. Unit nodes were considered as classical nodes.

HP. de Koning (ESTEC) asked whether the method was limited to rectangular shapes. JP. Dudon said that there was a constraint on using rectangular shapes at the moment.

3.6. Transient CPL modelling with ESATAN/FHTS and SINDA/FLUINT

C. Puillet (CNES) described work to model capillary pumped loops using FHTS and FLUINT, and the new capillary pumped elements in FHTS. (See Appendix O)

O. Pin (ESTEC) asked whether anyone else in the audience had used the capillary pumped loop (CPL) elements provided with ESATAN/FHTS 8.6. V. Perotto (Alenia) said that they had tried at Alenia, but they had used a simpler loop than C. Puillet had shown. The loop had consisted of only one evaporator and one condenser. They had found similar problems to the ones presented, such as the time step, and the sensitivity to the number of nodes. He was concerned about how well physical phenomena could be modelled. He wanted to know when a method would be available which got rid of the current test cycle of building the loop and running the tests just to verify the model.

O. Pin asked whether C. Puillet could be more precise about the physics which the loop had represented. What still needed to be investigated? C. Puillet answered that low mass flow rates leading to stratified flow had not been modelled, therefore the results were not accurate. It was

necessary to have a high mass flow rate in the experiment in order to give homogeneous flow.

O. Pin said that there was a paradox. It would be possible to add more physics to FHTS, but the real requirement for thermal engineers would be to get rid of FHTS. Everyone would be happy to overcome the use of fluid nodes.

O. Pin asked whether Alenia could provide more feedback on the problems they had experienced. V. Perotto explained that they had tried to get rid of the pre-built capillary pump elements. They had modelled specific capillary elements using subroutines, but they were still not happy with the result. They had a student who had been looking into this, but he was currently away on military service. He felt that rather than develop the tool further, there was a need to develop experience of modelling such loops. C. Puillet agreed that experience was needed which matched the models, for example, models having no stratified flow.

O. Pin said that one of the major problems had been how to test the CPL elements themselves (evaporator, condenser and isolator). The results had to be verified against unit testing of the elements themselves, and not in experimental loops. C. Puillet admitted that it was not easy to get a model to match the experiment.

3.7. Status of Model Data Exchange

HP. de Koning (ESTEC) described the growing interest amongst the tool vendors in STEP, and the current state of development of the STEP-TAS and STEP-NRF interfaces. (See Appendix P)

H.Rathjen (Astrium-D) asked how cut surfaces from ESARAD were handled by STEP-TAS and imported into other software tools. He had tried using STEP-TAS for converting ordinary surfaces from ESARAD to Thermica but had found that coordinate information was missing.

HP. de Koning said that all surfaces were converted to a point definition within STEP-TAS, so a rectangle which had been defined by width and height in ESARAD would be converted to use a P1, P2, P3 definition in STEP-TAS. The final coordinates also depended on how translations and rotations were handled in the database, so some intermediate coordinate transformation information might also be lost in the conversion. H.Rathjen said that losing coordinate information made model transfer difficult. HP. de Koning agreed. Another problem area was that labels were lost, but this would be corrected. In the current converters, this information was not properly mapped, but this would be fixed. Cut surfaces were not taken into account in STEP-TAS exchange. The existence of the surface was transferred, but not the surface itself. The primitive surfaces used as operands to create the cut surface were transferred, but not the resulting cut surface. Therefore the receiving tool needed manual intervention to handle the cut surface.

F. du Laurens (Alstom) remarked that user support had received many calls about transferring Thermica models to ESARAD via the STEP-TAS interface where there were a lot of statements such as SHELL A = SHELL B + SHELL B. He wondered whether this was a similar problem.

HP. de Koning admitted that there were several bugs in the converter which needed ironing out. The three different levels of interface used in the conversion all had bugs. This was one reason

to simplify the architecture, remove the old SET-ATS layer, and identify where the bugs occurred. The implementation of the converter for different tools had unearthed various bugs, issues to be resolved, and feature requests. These would all be corrected or consolidated in future releases. Even though it was a slow process, he felt that there was convergence.

M. Molina (Carlo Gavazzi Space) commented that Carlo Gavazzi Space and OHB had been using the Trasys to ESARAD converter successfully.

HP. de Koning said that anyone who was interested in using the converter should send him a request via electronic mail. There were a lot of test cases for the converter so it was relatively completely validated.

A. Robson (Astrium-UK) asked whether the opportunity existed to use the STEP protocols to transfer thermal results into finite element models. HP. de Koning said that Lockheed Martin had asked him to expand AP209² to include thermal data, but this was still under consideration. This would be a logical way of doing it. However, it would still take time. The other tools were slowly going the same way. Patran was the only tool which handled AP209 so far, so handling results was still limited.

4. Wednesday 10th October: Afternoon Session

4.1. Thermica v4.

P. Renard (Astrium-SAS) described the reasons behind the development of a new interface for Thermica, and gave a demonstration of the new GUI and interactive model builder prototypes. (See Appendix Q)

O. Pin (ESTEC) asked whether the multi-shape node shown in the interactive model builder used the centre of gravity for the conductive link. P. Renard replied that it was the geometric centre rather than the centre of gravity. The density of the material was not taken into account.

H. Rathjen (Astrium-D) asked whether the new user interface would allow the user to specify cutting tools. P. Renard answered that new shapes had been required in the geometry to handle cutting tools, but this had now been done. Work was still required on the ray-tracing to support cut surfaces, but the goal was to support cut shapes in Thermica.

V. Perotto (Alenia) asked for more details of the albedo and infra-red modelling. P. Renard said that currently the models used constant albedo or temperature values for the planets, but many people wanted to have different albedo or temperature values for different areas of the planet model. This could be achieved in the future by allowing the user to edit a table of values. V. Perotto asked whether such an infra-red model would compute the infra-red fluxes based on these temperatures. P. Renard replied that there would be no computation within the model. The temperatures could be used to model the effect of an atmosphere.

2. AP209 is the STEP protocol for the exchange of FEM data.

F. Koorevaar (Fokker Space) said that in previous versions of Thermica it had been difficult to see the difference between active and inactive surfaces. P. Renard said that this had been improved.

F. du Laurens (Alstom) asked to what extent did Thermica support the calculation of conductive links. P. Renard said that the contact conductance between classical shapes was handled, such as disk with cylinder, etc.

J. Persson (ESTEC) asked whether cut surfaces would be handled. P. Renard answered that conductive links for surfaces with boolean operations still needed to be investigated. The current idea was to re-mesh the cut shape and then check the conductive links.

A. Robson (Astrium-UK) asked whether it would be possible to run the conductive link calculation in batch mode. P. Renard admitted that batch mode was also important, but there was a need to prioritise which features went into the next version.

4.2. Developments in ESARAD, ESATAN and User Support

F. du Laurens (Alstom) and H. Brouquet (Alstom) described the latest developments in ESARAD and ESATAN, and explained the self-help ideas behind the Alstom web site. (See Appendix R)

A. Robson (Astrium-UK) remarked that the new cyclic solver routine in ESATAN would not converge if the model contained logic to control heaters. The model might converge by itself, but the heater would interfere.

HP. de Koning (ESTEC) asked whether the user could specify a range of nodes for which the convergence criteria applied. H. Brouquet said that this was possible, or the user could specify a sub-model.

O. Pin (ESTEC) said that the fact that the calling interface allowed the user to specify “ALL” or “NONE” was because future work was foreseen to implement events. This feature of the calling interface was the first step towards this implementation. HP. de Koning explained that events would be named, so the user would be able to specify a particular event.

F. Lamela (CASA) asked at what time the min./max. calculation took place. The user might be interested in partial values, of those at the beginning or end of particular time steps. What if the user only wanted the min./max. temperature after 52.55 seconds? O. Pin answered that when using the new cyclic solver routine the user might only want the min./max. values during the final solution stage. The user could specify when the STORMM routine was called. One way to do it could be to use the cyclic solver first, then run one additional orbit which contained calls to STORMM. H. Brouquet explained that the user needed to add some logic to the ESATAN model so that if the time was greater than a certain value, for example, STORMM would be called. F. Lamela was relieved that the model would not need to be restarted with different starting conditions in order to extract the correct min./max. values for a particular range of times.

In answer to a question from C. Williamson (Eutelsat), H. Brouquet said that the min./max. routine compared the variable which had been defined, and stored the result in other variables. HP. de Koning said that the user could access these variables if required. There was a minT variable for each node in the model. H. Brouquet said the user had access to all of the standard nodal attributes as well as those defined in USRNOD.DAT.

P. Renard (Astrium-SAS) asked whether the introduction of FlexLM would give rise to an additional cost to the user. F. du Laurens said that there would be no additional cost to the user. The use of FlexLM would allow the user to have 4 floating licences.

D. Labuhn (OHB) asked about the status of POLYTAN. F. du Laurens answered that POLYTAN was now a project rather than a specific product. New features of ESARAD would fall under the POLYTAN project. HP. de Koning explained that originally POLYTAN was to have been a new product. Work started in 1995/6 and there had been a number of prototypes for various aspects of the tools. However, it was decided that the POLYTAN product was just too ambitious, and there were likely to be problems with a smooth migration from the existing tools, and problems with backwards compatibility. Current space projects ran for many years, so there would still be a need to use the original tools for a long time, so the switch to a completely new tool would have been difficult to manage. POLYTAN functionality could only have been added a little bit at a time. Therefore the decision was made to provide a series of incremental upgrades to ESARAD and ESATAN, and to build the POLYTAN functionality into successive industrial releases of the existing tools. F. du Laurens announced that the version of ESARAD which could be considered as forming part of POLYTAN release 0 was scheduled for release in February 2002. HP. de Koning said that this version would feature better integration with ESATAN to allow splitting the model into the different ESATAN blocks, mission capabilities, and improvements to the visualisation.

E. Cosson (EADS) said that there was often a need to handle ESATAN internal variables for determining the heat balance, or to monitor the phase change of materials, or just to test the variables themselves. The QRATES routine gave the imbalance, but it was not possible to use this as part of a test. O. Pin asked whether he needed access to these variables in order to modify the user logic. The answer was yes: access to these variables was required. HP. de Koning said that it should be possible to declare a nodal entity and to check this entity in the user logic. He agreed that there was a need for someone to write some example code to show users how to do it.

V. Perotto (Alenia) had some comments on the latest version of ESARAD. He said that they had tried ESARAD 4.3.2, but it was not really being used. They were running across a network, and the processing times for the geometry were worse than the old version. Running the geometry took longer. HP. de Koning asked whether this was using the esrdg batch process. V. Perotto answered that this was just loading and processing the geometry in interactive mode. F. du Laurens suggested to process the geometry using batch mode and then load this into the GUI. V. Perotto said that he was not sure of the details, but he thought that the batch process was used, and then the geometry was loaded into the GUI. F. du Laurens said that it should only take about 10 to 15 seconds to load a 3000 node model.

V. Perotto said that they had also had problems with transfer orbits. To model Mercury orbiting the Sun, they had found some strange fluxes. It appeared there was a problem with solar

constants not being calculated. F. du Laurens said that the solar constant was currently calculated as the mean value over the transfer orbit, but this would be changed in the future.

V. Perotto said that to calculate the orbital fluxes for the Bepi Colombo mission to Mercury it had been necessary to have two runs in order to take Mercury's slow rotation into account. Mercury only had 3 planetary rotations every 2 Mercury years. However, modelling two successive orbits was not simple in ESARAD. HP. de Koning said that if the model contained 24 orbit positions but they were unable to run 48 orbit positions in sequence then this was problem. This needed to be investigated and resolved. V. Perotto said that they had run two models and then combined the fluxes.

S. Appel (ESTEC) asked whether the Web site could also be used for reporting problems. F. du Laurens said that this was not possible at the moment, but was an idea for the future. The user should be able to recall and track reported problems on line. He said that user support would continue to handle electronic mail, but the Web site should take over as the first point of contact. S. Appel asked if he sent electronic mail to user support, would his problem be added to the Web. Would he have access to the problem reports submitted by other users? F. du Laurens answered that there was no direct interface between the user support mail system and the Web site. Users would only have access to their own problem reports because of confidentiality issues.

4.3. Workshop Close

O. Pin (ESTEC) said that all of the presentations would be made available on the ESTEC web site, and people who were new to the Workshop would be added to the mailing list.

He said that producing the Minutes of the Workshop had to be on a best effort basis: it took a lot of work to produce the Minutes and there were always other tasks to be done.

He thanked Alstom and the other presenters for the effort they had made for the Workshop.

He hoped to see everyone again the following year at the next Workshop.

Appendix A: Welcome and Introduction

Welcome and Introduction

O. Pin
ESTEC/TOS-MCV

Appendix B: Managing the Interface between ThermXL and Esarad

Managing the Interface between ThermXL and Esarad

A. Robson
Astrium-UK

Appendix C: Introduction to G-DELTAN V3

Introduction to G-DELTAN V3

An Interactive Thermal Analysis Tool

C. Williamson
Eutelsat S.A.

Appendix D: Improving Ray-Tracing for Monte Carlo Simulations

Improving Ray-Tracing Algorithm for Monte Carlo Simulations

B. Shaughnessy
RAL

Appendix E: New Ray-Tracing Technique for THERMICA

New Ray-Tracing Technique for THERMICA

M. Jacquiau
Astrium-SAS

Appendix F: Report on TFAWS and Introduction to ThermPlot

Report on TFAWS

and

Introduction to ThermPlot

HP. de Koning
ESTEC/TOS-MCV

Appendix G: Artifis / Topic / ThermXL

Artifis

Topic

ThermXL

F. du Laurens d'Oiselay
Alstom

Appendix H: Stochastic Approach to Spacecraft Thermal Control

Stochastic Approach to Spacecraft Thermal Control Subsystem

F. Lamela Herrera
CASA

Appendix I: ESARAD

ESARAD

F. du Laurens d'Oiselay
Alstom

Appendix J: Round Table Discussion

Round Table Discussion

H.P. de Koning
ESTEC/TOS-MCV

Appendix K: Temperature Control Loop Analyzer (TeCLA) Software

Temperature Control Loop Analyzer (TeCLA) Software

F. Burzagli
Alenia Spazio

Appendix L: Analysis of Spacecraft Thermal Stability

Analysis of Spacecraft Thermal Stability

B. Shaughnessy
RAL

Appendix M: Overview of Bepi-Colombo Thermal Analysis

Overview of Bepi-Colombo Thermal Analysis

I. Renouf
Astrium-UK

Appendix N: CORATHERM for Spacecraft Thermo-Elastic Analysis

Application of CORATHERM for Spacecraft Thermo-Elastic Analysis

J-P. Dudon
Alcatel Cannes

Appendix O: Transient Capillary Pumped Loop Modelling

Transient Capillary Pumped Loop Modelling with ESATAN/FHTS and SINDA/FLUINT

C. Puillet
CNES

Appendix P: Status on Model Data Exchange

Status on Model Data Exchange

HP. de Koning
ESTEC/TOS-MCV

Appendix Q: Thermica v4

Thermica v4

P. Renard
Astrium-SAS

Appendix R: Developments in ESARAD, ESATAN and User Support

Developments in ESARAD, ESATAN and User Support

F. du Laurens d'Oiselay
Alstom

Appendix S: List of Participants

List of Participants

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Thermal and ECLS Software**

**9-10 October 2001
ESTEC, Noordwijk, Netherlands**

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