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# 19th European Workshop on

# Thermal and ECLS Software

**ESTEC, Noordwijk, The Netherlands**

**11-12 October 2005**

(Cover image courtesy of Alstom Aerospace and Maya Heat Transfer)

ABSTRACT

This document contains the minutes of the 19th European Thermal and ECLS Software Workshop held at ESTEC, Noordwijk, The Netherlands on the 11th and 12th October 2005. 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 | 2005-11-01 | Document creation |
| 1.1 | 2005-12-16 | Draft for internal comment |
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# Final Programme

19th European Thermal and ECLS Software Workshop
ESTEC, Noordwijk, The Netherlands
11th-12th October 2005

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| 10:05 | Presentation of the PC Version of the ESABASE/Debris Impact Analysis Tool<br>Holger Sdunnus, eta_max space, Germany |
| 10:35 | Review of Improvements in Thermica<br>Timothée Soriano, EADS Astrium, France |
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| 09:30 | AP203 to TAS converter:<br>A converter from AP203/AP214 to STEP-TAS models, based on open source technologies<br>Olivier Pailles, INCKA, France |
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| 11:30 | Thermica and Thermal Desktop Geometric modelling: a user perspective<br>Alberto Franzoso, Carlo Gavazzi Space, Italy |
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| 14:00 | Thermal Model Verification of the Planck LFI QM Instrument<br>Giorgio Baldan, Alenia Spazio, Italy |
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# 1. Tuesday 11th October - Morning Session

## 1.1. Introduction

H. Rooijackers (ESA/ESTEC) welcomed everyone to the workshop. He outlined the main goals of the workshop, and provided other organisational details. (See Appendix A)

As usual, the main goals of the workshop were:

- to promote the exchange of views and experiences amongst the users of European thermal and ECLS engineering analysis tools and related methodologies
- to provide a forum for contact between end users and software developers
- to present developments of the thermal and ECLS engineering analysis tools and to solicit feedback
- to present new methodologies, standardisation activities, etc.

## 1.2. ESABASE/Debris Impact Analysis Tool

H. Sdunnus (eta_max) described the development of a new PC version of the ESABASE/Debris Impact analysis tool. (See Appendix B)

O. Pin (ESA/ESTEC) asked about sensitivity analysis, and whether it was possible, for instance, to run fifty jobs in batch mode. H. Sdunnus said that there was no batch capability: it was a completely interactive tool.

C. Stroom (retired) asked why it had been necessary to develop a new ray-tracer, and whether it was available as open source software. H. Sdunnus answered that the intention was for all of the modules to be made available as open source software, including the ray-tracer. He said that the ownership of the original ESABASE ray-tracing code had not been clear - did it belong to ESA or not? - so they had developed a new ray-tracer to avoid potential distribution problems. The ray-tracer and the benchmark code would be available.

T. Jung (Fraunhofer Institute) asked whether Open Render and other open source ray-tracing software had been considered. H. Sdunnus said that they had looked at many of the open source tools, but most of them used similar principles, and that it would take a lot of work to convert the internal data to work with the interfaces. The basic algorithms behind the ray-tracing were simple, so they had simply decided that it would be faster to re-code from scratch using their own data structures rather than spending the time to work around the other interfaces.

HP. de Koning (ESA/ESTEC) asked whether the improvements to the Open Cascade code that had been mentioned had actually been fed back to Open Cascade. H. Sdunnus said that the development was still in the beta phase, so the improvements had not been fed back yet, but that they did intend to do so. One of the improvements was the ability to move the geometry objects using the mouse, for example.

## 1.3. Improvements to Thermica

T. Soriano (EADS Astrium) introduced himself as the new head of Thermica development, and described the new features to be released before the end of the year, and also the features of Version 4, to be released next year. (See Appendix C)

H. Sdunnus (eta_max) had noticed the STEP interface, and asked how STEP was handled and what APIs were supported. T. Soriano said that the new version used VTK, and that VTK provided an interface with STEP-203 files. P. Cheoux-Damas (EADS Astrium) said that Version 4 was based on Open Cascade, and would also provide an interface to CATIA.

N. Lavery (University of Wales, Swansea) asked what facilities were available for importing fluid data. T. Soriano said that there was no computation of fluid results in Thermica, but added that in Version 4 it might be possible to post-process HDF files that contained fluid information and display it.

J-P. Dudon (Alcatel) asked whether the calculation model was applicable to a volumetric mesh. T. Soriano said no, not yet. They were waiting for Version 4 and future developments.

H. Hellman (Swedish Space Corporation) asked about the new parallel time-stepping approach in the thermal solver: how did the user configure it, or was it automatic? T. Soriano said that it was handled automatically. The nodes were separated per time step, and then checked to see whether the accuracy had been achieved. Those nodes which had failed the accuracy check were then re-computed using a smaller time step. Then there was an interpolation using Crank-Nicholson to recreate the complete environment.

G. Tonelloto (ESA/ESTEC) asked whether the analytical shapes mentioned also included the facility to define them using equations. T. Soriano said that they only handled pre-defined shapes in Thermica and Systema, such as the sphere, parabola, etc. However, they had defined some compound shapes, such as the antenna.

## 1.4. ESATAN Thermal Suite

H. Brouquet (ALSTOM) described the concept of the ESATAN Thermal Suite as a single product that now contained ESATAN/FHTS, ThermXL and ThermNV in one package at no extra cost to the user. He went on to describe the current developments in the individual tools. (See Appendix D)

S. Dolce (ESA/ESTEC) asked whether the goal of handling three hundred thousand nodes and seven million conductors in Esatan 9.6 had come from a user request, or just a challenge. H. Brouquet said that it was a real requirement arising from the need to import FE models. C. Stroom (retired) said that FE models typically contained hundreds of thousands of nodes and wondered why three hundred thousand had been chosen as the target. H. Brouquet said that they had wanted to at least be able to handle ‘average’ FE models, and three hundred thousand nodes seemed to be an average for the models that they had seen. J. Thomas (ALSTOM) said that they were aware of a specific model with this number of nodes and conductors, and had used these numbers as guidelines for where analysis would go in the future. He said that the tools could in fact handle many more nodes and conductors than this model.

S. Dolce said that being able to handle such large models was good from the software point of view, but doubted whether any user could really understand such a large model. J. Thomas agreed with him, and said that he was not advocating that people should build such large models just because they could, but said that this capability was essential if dealing with large models coming from thermo-elastic analysis for example.

R. Pérez (Iberespacio) commented that he had experienced problems when running ThermXL 3.0 under Windows XP and wondered what the system requirements were for the new version. H. Brouquet said that the requirements were not on the version of Windows as such, but more on the version of Excel that was being used. J. Etchells (ESA/ESTEC) commented that he had not been able to run the auto-installer under Windows 2003 Server.

## 1.5. Outcome of Harmonisation Activities

O. Pin (ESA/ESTEC) described the founding and original aims of the Steering Board for the Harmonisation of Thermal and Space Environment Analysis Software and Interfaces, and what it had been able to accomplish, all by concensus. He summarised the new ESA policy and outlined where the activities would go in the future. There would be a Steering Board meeting in parallel with the workshop to discuss its future role. (See Appendix E)

M. Heuts (Dutch Space) asked about the industrialisation and development of new tools such as ESATAP. O. Pin said that because ESATAP had only been at the conceptual phase when the new harminisation policy had been adopted, it had still been possible to try to steer ESATAP to become a toolbox which could be provided to developers to use in building tools, so the developers' software requirements had also been taken into account. However, with the benefit of hindsight, if the Harmonisation policy would have already been in place before ESATAP had started, ESATAP would have been handled in a completely different way.

O. Pin said that the Thermal Concept Design Tool, being produced by Blue and Alenia, was a different matter, because it was an expert tool. He gave a loose definition of an expert tool as one which, if ESA did not do it, nobody would. The TCDT would be useful for phase A studies, and it would probably have fewer than ten users. Therefore there was no business case for commercial developers. If ESA didn't sponsor the TCDT, it would remain a nice idea that would never be built.

C. Stroom (retired) said that there had been an omission on the slides: he felt that the publicly funded developments should be made available to both ESA states and individuals as well. HP. de Koning (ESA/ESTEC) explained that the usual 'ESA-speak' referred to 'Persons and Bodies' in the ESA member states.

## 1.6. ESATAN-TMG

J. Thomas (ALSTOM) described a joint venture between ALSTOM and MAYA to interface ESATAN and TMG. This would be a new tool, and not part of the ESATAN Thermal Suite, although the user would need to have ESATAN in order to be able to use it. (See Appendix F)

S. Dolce (ESA/ESTEC) asked whether there were already plans to have an interface between NASTRAN and ESATAN. J. Thomas said that the link already existed. TMG provided a graphical interface layer for pre- and post-processing and also the import of data from both NASTRAN and ANSYS. He said that ESATAN-TMG provided a mapping between Thermal and FE modelling. The engineer could use whatever environment or tool to generate a NASTRAN file and then use this as input for the thermal modelling by importing via TMG. S. Dolce asked whether it would be possible to go from NASTRAN to TMG and then to ESARAD as well as ESATAN. J. Thomas said that the user could generate ESARAD, but could also use the inherent capabilities of TMG to define the orbit and model and then use ESATAN for the solution. The result data could be mapped back to a similarly meshed model in ANSYS or NASTRAN.

G. Baldan (Alenia Spazio) said that he had used rigid elements in IDEAS to connect electronics boards, and had then found them difficult to convert properly. He wanted to know whether ESATAN-TMG would handle rigid elements that were used to connect elements with different meshes. C. Ruel (Maya HTT) said that the tool didn't support rigid elements at the moment. G. Baldan (Alenia Spazio) told J. Thomas that rigid elements were of particular interest to him.

N. Lavery (University of Wales, Swansea) asked whether the ESATAN-TMG provided any access to CFD for plume impingement calculation. J. Thomas said that it was not currently provided in the environment.

J. Etchells (ESA/ESTEC) asked how the tool handled the NASTRAN mesh, because he understood that TMG was based on volumes, therefore the GL representation was true for the FE model, but not for the control volume approach. C. Ruel replied that the control volume was constructed from finite volume elements, and from there it was possible to go to the lumped parameter representation. J. Thomas admitted that the GL representation was not part of the FE solution as such.

A. Robson (EADS Astrium) asked whether the GL calculation was based on the FE or the lumped parameter model. When the GLs were calculated, were they physical representations or mathematical? J. Thomas said that the calculation did not work in the same way as the Automatic Conductor Generation in ESARAD. A. Robson said that meant that the result was a black box representation. J. Thomas argued that most engineers validated their models by applying heat loads rather than looking at individual conductive links, so the models were already treated as black boxes. J. Thomas said that the LISA model had come from an FE model and it was too large and complex to be inspected directly.

A. Robson asked whether ESATAN-TMG was part of the ESATAN Thermal Suite. J. Thomas said, that they were separate products. ALSTOM regarded ESATAN as core to their business in the future, and therefore there was a need to make it pay. That was plain business sense. He said that this was another reason why tools lasted so long: there was a lot of investment by developers as well as users.

M. Gorlani (Blue Group) said that if it was possible to import a mesh and export the results, would it also be possible to import NASTRAN and export ANSYS? J. Thomas said that this was an obvious extension that they would be looking at in the future.

C. Stroom (retired) asked what happened in the case where the FE model contained things that were not needed for the thermal analysis. J. Thomas answered that handling surperfluous detail when converting from FE to thermal was not unique: similar handling was also needed in the opposite direction. Thermal models could define heaters, switching logic, specific boundary conditions, and even user logic that were of no interest to the structural user. C. Stroom asked whether there was any means of keeping the models in synchronisation so that the respective users didn't have to keep making the same changes every iteration. J. Thomas said that some thermal analysis constructs could not be passed back to TMG as such because they didn't exist in the FE model. However, it was possible not to lose the information between iterations by re-synchronising with the old file. There were options on what to keep and how to resolve conflicts between the thermal and FE models.

C. Stroom asked whether it would be better for the FE model to be defined in terms of the thermal requirements. J. Thomas said that the user could define the FE model, and then define the mesh separately for thermal use. When going the other way, the user could control the mapping in order to handle the structural features that have no thermal requirements. The proximity mapping within the tool would allow for handling holes, etc.

HP. de Koning (ESA/ESTEC) said that what happened now was that users imported the FE model and then added thermal properties to it. Would it be possible to incorporate the thermal properties directly into the FE model? J. Thomas said that if the properties were already in the FE model then they would be imported. However, there were a lot of extra properties that needed to be handled, and what would be going into Version 1 of the tool in 2006 was still under discussion. The mechanics of how to do it was already known, but it was a question of which version would contain the implementation. HP. de Koning said that in an application such as this it was typical to loop through the various analysis processes for thermal, stress, etc. so the user really wanted the properties to be retained throughout the loop. C. Ruel said that this was the reason why the tool allowed the user to keep the properties in the environment.

## 1.7. ThermNV Status

H. Brouquet (ALSTOM) described the latest version of ThermNV, the thermal network viewer tool that was part of the Esatan Thermal Suite, including many features that had resulted from direct feedback from users after the previous workshop. He then gave a demonstration of the tool. (See Appendix G)

M. Molina (Carlo Gavazzi Space) asked about the level of compatibility between Version 1 and Version2. H. Brouquet said that they were compatible, so the user could go back and forth between the two versions, but obviously there were more limited features in V1. M. Molina asked about the size of an "empty" file, i.e. one representing a network containing no nodes. His reason for asking was that an "empty" file in SINAPS was 1Mb! H. Brouquet answered that the network he had shown during the demonstration was represented in only 20kb. J. Thomas (ALSTOM) explained that the network data and the XML layout file were separate. H. Brouquet opened an XML file on screen to show that it contained a link to the GFF file.

R. Nadalini (DLR) said that in ThermNV V1, the calculation of heat flow had used the temperature and GL data. He wanted to know if ThermNV V2 was still doing this, and if so, how to solve the problem of heat imbalance. H. Brouquet answered that if the GFF data recorded an imbalance then ThermNV would also show that imbalance. ALSTOM had designed ThermNV for use in model checking. If ThermNV showed that there was an imbalance in the model, then the user would need to go back to the ESATAN input deck to correct it.

# 2. Tuesday 11th October - Afternoon Session

## 2.1. Integration of Monte Carlo Methods with TMG's Suite of Radiation Analysis Tools.

C. Jackson (Maya HTT) described the advantages and disadvantages in using the Matrix Method, the Hemicube Method and Monte Carlo ray-tracing in the various stages of spacecraft themal analysis. (See Appendix H)

HP. de Koning (ESA/ESTEC) made the remark that one reason not to use Monte Carlo ray-tracing was when the model contained a mixture of very large and very small surfaces. C. Jackson agreed and said that the techniques worked on an enclosure basis, so it should be possible to use different techniques for different enclosures.

J. Etchells (ESA/ESTEC) asked whether the meshing strategy allowed the support of both higher order elements and Monte Carlo ray-tracing. C. Jackson confirmed that it did.

## 2.2. ESARAD Status

B. Castelli (ALSTOM) described the new features available in the versions of ESARAD that had been released since the last workshop and those that were planned for release at the end of 2005 and early in 2006, such as planet temperature maps, property sets, orbital arcs and the use of OpenGL. (See Appendix I)

S. Kaspar (Jena Optronik) asked whether it would be possible to use old models without changes. B. Castelli said that the user would need to reload the models again from scratch, but this could also be done in batch mode. M. Gorlani (Blue Group) wanted confirmation that a model written for ESARAD 5.6 could be loaded in 5.8. B. Castelli said this was possible, but it wasn't possible for a 5.8 file to be read using 5.6 because 5.6 would not recognise the new features. However, it should always be possible to read an old file with the new version.

H. Rathjen (EADS Space) asked how the new OpenGL interface displayed node numbers on the model. B. Castelli said that the visualisation of node numbers on the model remained unchanged compared to the GPHIGS version. He demonstrated this on the screen and admitted that the display was unclear. So far, they had not discovered any way of simplifying the display to make it clearer.

M. Molina (Carlo Gavazzi Space) remarked that both ESARAD and Thermica had been improved to handle the Sun with finite size at a finite distance from the planet. He joked that early astronomers had known about this in the third century before Christ..He was interested to know whether spacecraft thermal engineers would actually need to use this feature. B. Castelli said that this had been a specific feature request for Bepi-Colombo, and the Solar Orbiter would use it. HP. de Koning (ESA/ESTEC) said that, basically, this was important for missions that were close to the Sun.

M. Molina asked whether the Orbital Arcs described were simply geometrical representations, or whether they included Newton’s Laws. B. Castelli said that the arcs included Newton’s Laws. J. Thomas (ALSTOM) explained that there was an option so that the user could define an offset in order to chain the arcs together. If ESARAD could match the arcs together it would produce a single table of times. He added that the user could also specify a set of points to be used on each arc, so there was full control. HP. de Koning said that the user could use STK or SABR to define the points and then use these as input to ESARAD. J. Thomas said that the user could even define an orbital arc consisting of a single point and use this to define exotic pointing modes.

M. Molina returned to the finite distance to the Sun. He said that calculations for satellites in Earth orbit usually assumed the Sun at an infinite distance. HP. de Koning said that even at the distance of Mercury from the Sun the effect was only one degree, but when taking the higher solar flux of about ten solar constants into account even one degree made a significant difference. M. Molina (Carlo Gavazzi Space) admitted that it would be useful when calculating fluxes for planets near the Sun that had no atmosphere, but maybe not for Venus with atmosphere.

## 2.3. A Finite Element Radiative Heat Transfer Software for Internal and External Aero-Thermal Applications

N. Lavery (University of Wales, Swansea) gave a lightning tour though a large number of slides showing the types of problems to be overcome when considering heat exchange in terrestrial systems that included convective flow, leading to the development of the PHARO software. (See Appendix J)

C. Jackson (Maya HTT) asked about the calculation of the apparent temperatures: did the software use a particular view or consider different directions? N. Lavery said that the customer, DSTL, had provided environmental scenarios generated using its own internal software. This information had simply been passed to PHARO.

C. Jackson noted that the model was dependent on the light spectrum, and asked whether the spectrum was considered using average properties, or whether it was split into different infra-red bands. N. Lavery said that the internal calculations could be broken down into a series of lumped flux exchanges, but the solar loading calculations might need a different method. C. Jackson wondered how useful it was to use spectral bands. N. Lavery said that they were interested in the different spectral bands because that was how the thermal imaging cameras worked, and they needed to match the results to the thermal image. Measurements related to “three pixels in white in band A”, etc. gave the thermal signature.

C. Ruel asked whether the test data would be published, or whether it was classified. N. Lavery said that the Gnome engine results were not classified, and he was hoping to publish the results before next summer.

## 2.4. Interface Software Development for Patran/Thermal, Esarad and Thermica

C. Heller (EADS Astrium) described the analysis data flow between structural and thermal analysis, and some small converters designed to bridge the interfaces between the disciplines and the tools used. (See Appendix K)

S. Appel (ESA/ESTEC) commented that although C. Heller had expressed some reservations about P/Thermal’s calculation method for conductor and capacitance generation, most NASTRAN and ABAQUS users simply assumed that the developers had tested the implementation and that the results were correct. C. Heller admitted that this was the same answer that had been given by MSC. C. Heller knew that many companies used the NASTRAN toolbox, but he was still a little uneasy that he could not verify the method himself, and was forced to accept it as a black box solution. He felt that the customer really needed to have a clear statement about the validity of the method.

S. Appel noted that the methods calculated temperatures using a coarse thermal mesh which were interpolated in Patran, and this implied full trust in the conversion and interpolation process. The latter was a geometrical process. He asked whether C. Heller was sure that the continuous conduction or thermal property distribution over the structural model was still allowed. C. Heller said that he was sure for two reasons. The first was that the method used the same edge points, and therefore used the same mesh, so there was no interpolation, or extrapolation or possible gaps. The same edge coordinates were used to create the geometry. The second reason was that the Patran interpolation routine had been used for years, and it was possible to check what had been done. The Patran GL codes could not be checked. Therefore the interpolation method could be trusted, but not the conductor generation. S. Appel commented that if the model contained non-uniform thickness geometry then this method could not be used. The thin dish geometry shown should be OK.

C. Ruel (Maya HTT) said that it would be relatively easy to check the P/Thermal conduction model. To verify the accuracy, simply take a rectangular plate and put a heat load on one end, and then check the results against a hand calculation. Then redo the calculation using a triangular mesh. This would be an easy test. C. Heller agreed. He said that if the linear conduction could be semi-automated then there would be no need to use the Patran GL codes. This would be a huge gain for the user.

H. Hellman (Swedish Space Corporation) asked what process was used when converting from the fine FE mesh to the coarse FD mesh. Was it based on elements and node positions, or parametric geometry? C. Heller answered that the conversion used the point geometry from the edge nodes. Generating a coarse mesh could be done by hand as it was a relatively efficient process with the user clicking on surfaces from within the Patran tools.

C. Stroom (retired) had been surprised by the apparent comparison of the two thermal figures, because as far as he could see the one on the right hand side was significantly cooler. C. Heller admitted that the images on the slides did not match because they came from different analysis runs. He apologised for any confusion.

## 2.5. Integrating Finite Element Analysis into the Spacecraft Thermal Analysis Process.

J. Etchells (ESA/ESTEC) described the Python tools that he had developed during his year at ESTEC as a young graduate trainee, and how they could be used in round-trip analysis using both FE and Thermal lumped parameter tools. (See Appendix L)

R. Nadalini (DLR) commented that the analysis process shown would require a large investment in terms of time, commitment and tools to be learned. He felt that the hybrid approach looked interesting, but wondered how many people it would take to make it work. He said that most FE tool experts did not know how to use ESATAN and ESARAD, and a small institute such as his had only one thermal engineer. J. Etchells explained that the approach shown required PATRAN or NASTRAN, possibly ESATAN, and then either ESARAD or Thermica. As far as the number of people was concerned, he felt that the tools were relatively intuitive, especially to the new generation of students who might not know anything about thermal lumped parameter methods but who did know how to use CAD and FE tools. The thermal lumped parameter tools were quite intuitive.

N. Lavery (University of Wales, Swansea) asked why it was necessary to use ray-tracing from the nodes. J. Etchells said it was not necessary, but it was functionality that would be useful. This would allow the user to do mapping of the faces, run the ray-tracing on those elements, and then distribute the result using shape functions. The ray-tracing would be done assuming an isothermal geometry. N. Lavery asked whether J. Etchells had experimented with a random location for the node. J. Etchells answered that he had used ESARAD for the ray-tracing. J. Thomas (ALSTOM) said that ESARAD chose random positions on the surfaces for the ray-tracing.

M. Molina (Carlo Gavazzi Space) was interested in the example of how to map the grids into ESATAN. He said that this was not how the thermal engineers have been trained. If the centre of the element was taken to represent the location of the node, how did the shape function approach work when compared to the thermal lumped parameter node. He was interested in both the radiative and conductive aspects. HP. de Koning (ESA/ESTEC) said that the approach used a staggered grid where the standard grid was shifted by a half cell and therefore did not lose any information. J. Etchells said that it was necessary to create a thermal lumped parameter entity model and then concentrate on how to interface this rigorously. M. Molina asked how to inject the power in a consistent way using a shape function. J. Etchells replied that it was possible to apply power from within NASTRAN or PATRAN. It was also possible to do it from within ESATAN, but the user again had to consider how to do this rigorously.

M. Gorlani (Blue Group) wondered whether the method was sensitive to the mesh being used, and asked whether there had been any analysis into which ones worked. J. Etchells said that it would be possible to validate the method by taking the conduction mesh and then solving with both PATRAN and ESATAN and comparing the results. He admitted that it was necessary to assume that both tools gave true and accurate results. M. Gorlani noted that J. Etchells trusted the NASTRAN results. J. Etchells answered that he had used PATRAN to generate the NASTRAN mesh. HP. de Koning added that there had been no calculation, just the generation of the geometry. J. Etchells said that it was possible to use different formulations to create the mesh, and that there were guidelines within NASTRAN about checking the mesh quality. It was not possible to take the results at face value: the user needed to validate the results. M. Gorlani noted that the same problem existed with the results from ESARAD and Thermica.

# 3. Wednesday 12th October - Morning Session

## 3.1. Open Standards, Thermal Analysis and STEP-TAS

HP. de Koning (ESA/ESTEC) described the growing recognition for open standards in engineering in general, and not just in space thermal engineering, because easy interchange of data was important for the early verification of engineering models. He went on to describe the progress being made in the space thermal field with STEP-TAS. (See Appendix M)

T. Jung (Fraunhofer Institute) asked whether STEP-TAS was specific for space thermal analysis. HP. de Koning said that the geometry and units handling were not specific to space, but other concepts such as orbits, arcs, and pointing based on orbit or space coordinate systems were clearly space specific. He said that those modules which did not need specific internal space or thermal knowledge did not have it, but used an external dictionary instead. These modules could be used in automotive engineering for instance. Airbus were currently looking at using parts of STEP-TAS.

M. Molina (Carlo Gavazzi Space) asked for feedback about the evolution of STEP-TAS within commercial software and in the US thermal community. HP. de Koning said that he was working closely with Georg Siebes of NASA and Ron Behee of SINDA-G fame. There would be a workshop in December with US tool makers and the NCSA who were responsible for HDF5. Work would start soon on the implementation of STEP-NRF using HDF5 in SINDA-G. He also had contacts with Brent Cullimore, the developer of Thermal Desktop.

O. Pin (ESA/ESTEC) said that part of the problem of commercial implementation was that ESTEC were still waiting for agreement on an Open Source licence under which the STEP-TAS libraries could be released. So far the libraries were only available at the ESA level. Once the licence became available then it would be possible to open developments with the US and the rest of the world. HP. de Koning confirmed that use at the ESA level had been agreed with the legal department, but working out the details would take time.

M. Molina asked about the TRAC system mentioned in the presentation. He assumed that each thermal engineer would require some level of training to use it. HP. de Koning agreed, but said that it would be possible to roll it out using just a couple of people in a team. It was easy to use, and much better than previous CVS-based systems. It was web-based, and it was possible to install it and have it working within an hour. It came with a TRAC-admin tool to allow for some customising of the interface, such as the levels of bug reports, etc.

## 3.2. A converter from AP203/214 to STEP-TAS models, based on Open Source technologies

O. Pailles (INCKA) described the development of a tool for reading geometric data from STEP AP-203 and AP-214 format files, recognizing certain facet constructions, and converting them into STEP-TAS entities. E. Ciuti (HANOP) demonstrated the tool and demonstrated the results using Baghera View. (See Appendix N)

C. Heller (EADS Astrium) asked about the model simplification philosophy: did the software simply detect all fillets and holes and then ask the user to accept or reject them, or could the user customise the behaviour? E. Ciuti said that for the fillets, if the intersection points were not good, the user received a warning. C. Heller said that the geometry creation depended on the CAD user. Would the simplification algorithm work with the extrusion process that many users worked with? Was there a difference between using cylinders and B-splines? E. Cuiti said that the initial model was read using Open Cascade, and so any model was directly converted to a set of faces. C. Heller said that a set of faces representing a cubic spline, for example, would give problems. The classical approach had been to click on the B-splines and then auto-mesh them, without trying to recognise any primitive shapes. HP. de Koning (ESA/ESTEC) said that the simplest approach would be to convert everything to triangles, but ray-tracing applications preferred fewer curved surfaces rather than thousands of triangles. This also related to the fidelity of the model, for optical instruments, etc. The use of facets gave a different ray-tracing result than mathematical curved shapes.

C. Heller asked whether there was any intention to have a connection to the structural tools too. HP. de Koning said that there was already CAD-to-FEM activity being sponsored by CNES. It would be interesting to see how both activities progressed. He hoped that CNES would make it available via the R&D pool. E. Werling (CNES) confirmed that CNES had an intermediate tool.

P. Cheoux-Damas (EADS Astrium) commented on the steps shown for the suppression of bolts and holes. He felt that this should be done by the design office in the original CATIA model, and not by the thermal engineers. This would result in smaller and better files for use by the thermal engineers. HP. de Koning said that this was true, but the best approach would be for the designer to be aware of the analysis needs, to maintain the complete model but suppress the details before analysis. In practice however, the CAD model often came from a prime contractor or was delivered by a sub-contractor, so the designer and the analyst were not in close contact. P. Cheoux-Damas agreed that not all simplification was needed at all levels, but felt that the first level of simplification should be carried out at the design office. O. Pailles commented that the conversion process was dependent on the ‘quality’ of the model in the AP203 file.

E. Werling said that how model conversion and simplification were handled depended on the size and expertise of the design office team. There were many tools in operation in industry, and large users such as ASTRIUM had sufficient dedicated people to be able to handle a wide range of tools. CNES also had enough people who knew the different requirements for different sorts of analysis. He admitted that there were two kinds of users, the large ones like ASTRIUM and CNES, and the small teams that used a more limited number of tools and who really needed automated conversion tools. He felt that the converter was a good solution for the small teams.

E. Werling wanted to know when the product would be available, and what the strategy would be. Would it be freeware, or open source software, or a commercial tool? E. Lebègue (HANOP) said that the converter would form part of a family of open source STEP-TAS products. HP. de Koning noted that it would fall under the community open source licence, and would be available to 'persons and bodies' in the ESA states. He hoped that the licence, and therefore converter, would be available at the beginning of next year.

C. Stroom (retired) commented that in the past there had been the idea of using filters for model conversion. Did this converter fall in line with this idea? HP. de Koning said that the thermal shapes were not part of the AP203 I/O model. This converter was a tie-in to recognise those shapes which were not handled by AP203. C. Stroom said that this could have been done before, so this converter was a deviation from the filters idea.

## 3.3. Baghera View Version 3

E. Lebègue (HANOP) described the latest developments made to Baghera View, the visualisation tool that could read STEP files. F. Coudret (CSTB) demonstrated the tool, its speed and performance, and the ability to highlight the differences between two versions of the same model. E. Lebègue described how STEP was increasingly being used in different engineering sectors and showed a short film on the use of virtual reality simulations to inspect and review architectural and engineering models. (See Appendix O)

P. Cheoux-Damas (EADS Astrium) said that if Baghera View was to be distributed across Europe, the menu system would need to be converted from French to English. HP. de Koning (ESA/ESTEC) said that he had seen both the French and English versions. P. Cheoux-Damas noted that Baghera View depended heavily on the Windows platform.

O. Pin (ESA/ESTEC) praised CNES for the decision to allow the free distribution of Baghera View within Europe, as this fitted well with the ESA and harmonised strategy in the thermal analysis domain. It would be useful if CNES could help push for the permission to distribute the tool to Canada as well in order to support the validation of interfaces in the Canadian tools.

H. Rooijackers (ESA/ESTEC) had noticed that the report files could be output via XML to Microsoft Office. He wondered whether this was standard XML, or Microsoft XML. E. Lebègue confirmed that it was standard XML. He said that only a subset of the numeric and nodal data could be exported. The EVE Office Wrapper could then be used to analyse the XML to generate a document, and this was only available on Microsoft platforms.

E. Werling (CNES) said that Baghera View would be made available soon, and asked people to make comments for improvements. He would try to find funding for the improvements. So far there were only a few users, so there would be a need for a transition period for improvement as more people used the tool.

E. Lebègue said that he had already agreed with T. Warrot (CNES) to have a web page. He hoped that the ESA web site would point to the CNES page.

## 3.4. Advances in Two Phase Capillary Loop Modelling with EcosimPro

C. Gregori (Iberespacio) described the improvements made in the capillary loop modelling since her presentation at a previous workshop. (See Appendix P)

R. Nadalini (DLR) asked whether the graphs shown of temperature oscillations were the simulation results, or actual test results. C. Gregori said that they had used verified data from published papers, and had checked these experimental results against the simulations.

R. Nadalini said that the presentation had shown the efficiency of the LHP system with EcosimPro, and asked how well the communication with ESATAN worked. C. Gregori said that the communication was efficient, so the overall simulation time was basically the sum of the EcosimPro and ESATAN times.

F. Jouffroy (EADS Astrium) noted that the presentation had shown reduced modelling in ESATAN and wondered what boundary conditions had been used and whether there had been any stabilisation problems. He had tried to use the TSINK with a real radiator and had encountered problems. C. Gregori said that the stability depended on where you put the connection interface. F. Jouffroy said that when using a decomposition model approach, of working in EcosimPro, feeding results to ESATAN, and then recalculating in EcosimPro, if the modelling of the condenser in ESATAN was too free it would be difficult to achieve convergence.

R. Pérez (Iberespacio) said that the two-phase loop model in EcosimPro is very efficient. The EcosimPro solver was better than many other solvers. In an orbit simulation there would be other inputs, but EcosimPro would be quicker than ESATAN. He pointed to one of the graphs and explained that each oscillation corresponded to one orbit. Each orbit period was 18 hours, but this could be simulated with 1 hour of CPU time.

P. Cheoux-Damas (EADS Astrium) returned to the convergence problem and said that it was difficult to tell where problems originated when using multiple tools. R. Pérez argued that in his experience the opposite was true. If there was a thermal specialist working with one tool and a fluid specialist working with the other tool, when it came to meshing one model to another there was a need to set an appropriate connection interface. He said that EcosimPro used a very stiff solver and did not have stability problems. P. Cheoux-Damas said that convergence problems were due to the physical limits of the test subjects. R. Pérez argued that this simulation had not introduced an untested thermal network into EcosimPro, but rather had introduced a tested component into ESATAN. The component had already been tested against experimental data, and it worked. There was still a question of the connection interval, and this depended on the time response of the radiator.

R. Nadalini said that in many cases it was necessary to integrate two very different and separate models. He had used breadboard models where everything had been integrated together, but as soon as this had been added to the main system there had been stability problems. These were partly due to the available tools. When you had a system comprising electronic boxes, radiators, loop heat pipes, etc. how was it possible to model each of the separate components if they formed one unit? R. Pérez said that before any integration with ESATAN, you could model the radiator in EcosimPro. You could provide the boundary conditions from the ESATAN model to EcosimPro and test these values. When you moved the model to ESATAN, simplify the model to use tubes and plates. You could check the values produced in the preliminary model, then eliminate the plates and connect to the thermal network.

## 3.5. Thermica and Thermal Desktop Geometric modelling: a user perspective

M. Molina (Carlo Gavazzi Space) presented the work of a colleague, Alberto Franzoso, who had been unable to attend. He described the differences in the geometric modelling process in Thermica and Thermal Desktop. (See Appendix Q)

T. Soriano (EADS Astrium) responded to the Thermica problems. He said that the T4Star modeller that would be part of the next release would correct most of the problems that were mentioned with T3D. He said that it was possible to post-process the ESATAN results if the user linked the ESATAN model against a library supplied with Thermica in order to give an NTP file that could be imported into Thermica.

HP. de Koning (ESA/ESTEC) had a remark about the conversion from SINDA to ESATAN and the limitation of only a single level of sub-models. He suggested to use TASverter to do the conversion and then use the renumbering option in order to shift each sub-model into a different node number range.

M. Molina asked whether TASverter would also have handled the problem with the mirroring within the geometric model. HP. de Koning confirmed that he could have used TASverter for the renumbering.

## 3.6. Genetic Algorithms assisted ESATAN modelling

R. Nadalini (DLR) described cross-fertilisation of ideas from different tool experts at DLR and how it had given rise to the application of genetic algorithms to ESATAN modelling, as well as other scientific uses of ESATAN modelling. (See Appendix R)

C. Jackson (Maya HTT) asked how it was possible to be sure that there was a single unique solution, because there could be two sets of properties that gave the same results. R. Nadalini said that they were dealing with a physical system, so it didn’t make sense for a property to have more than one possible value. For small error bands, they had calculated a lot of curves which were very close to the experimental results. In theory the genetic algorithm technique would try everything in order to find the best solution. He agreed that if there were two local maxima, then there could be problems, but this was unlikely in physical systems. They were working with a level of variation of within one percent, but there were many possible sets within this level of error, so it was necessary to test all sets.

M. Gorlani (Blue Group) asked whether stochastic techniques had been considered. R. Nadalini said that they were dealing with ten thousand cases because of the different parameter sets and that their in-house experience was with genetic algorithms and not stochastic modelling. He agreed that it could be interesting to try stochastic methods, but he had no experience of using them. Most of this work had been done using zero budget in his spare time.

T. Jung (Fraunhofer Institute) asked whether they had considered using parallelising applications so that they could run multiple analyses at the same time. R. Nadalini agreed, but said that running analyses in parallel ran into problems with the number of licences. He said that these were relatively simple issues but they were show-stoppers.

O. Pin (ESA/ESTEC) reminded everyone that ESA had sponsored a study into the use of stochastic methods and that the results were available free of charge via the ESTEC/TEC-MCV web pages[1]. All that was required was an investment of time. As far as the genetic algorithm approach was concerned, there had been a TRP proposal to look at using genetic algorithms for satellite level test correlation. However, he said that the status of the proposal was unclear: there could be an ITT soon, or if not, maybe it would be possible to set up a study that could be made available to the wholecommunity.

## 3.7. Thermal Model Reduction: algorithms and validation criteria

M. Molina (Carlo Gavazzi Space) summarized the presentations on thermal model reduction benefits and methods made by EADS Astrium and ESA/ESTEC at previous workshops, and introduced the ‘working volume’ concept to describe the limits of the range of validity of reduced models. (See Appendix S)

M. Gorlani (Blue Group) asked which principles were used to compare the temperatures during the verification. M. Molina replied that the reduced model should produce the same average temperatures as the detailed one. M. Gorlani said that the stochastic approach, and also a real test, used a cloud of results. M. Molina said that there should be an equivalent number of tests in order to improve the statistics.

O. Pin (ESA/ESTEC) said that having a detailed or reduced model defined a working volume. He wondered whether it would be possible to turn the problem around and have a detailed model and working volume for confidence, but provide guidelines on producing a reduced model. This was what was really wanted. M. Molina replied that it was really an inverse problem, so it couldn’t be handled that way.

O. Pin said that there was a proposal for a GSTP activity, but the community had to be clear on what method it actually wanted. France was the only sponsor of the proposal, so it was likely that the activity would go to Astrium and Alcatel.

M. Molina said that the lack of agreed definitions lead to the use of ad hoc solutions that were not generally applicable to the whole community.

1. Please visit **http://www.estec.esa.int/thermal/tools** and go to the **Modelling** section

J-P. Dudon (Alcatel) asked how M. Molina calculated the average temperature for a surface. M. Molina said that he used weighted averages over the areas.

J. Etchells (ESA/ESTEC) commented that at the previous workshop M. Molina had discussed the use of Laplace transforms over the state space. He wondered whether this had been considered: such techniques were already used in electronics. M. Molina said that they had not been considered.

P. Cheoux-Damas (EADS Astrium) said that this had been an interesting presentation, and that the working volume concept needed further investigation.

# 4. Wednesday 12th October - Afternoon Session

## 4.1. Thermal Model Verification of Planck LFI QM Instrument

G. Baldan (Alenia Spazio) presented the process needed to verify the Planck Low Frequencey Instrument using dedicated cryo-chamber test hardware with a limited number of temperature sensors, and related analysis model. He went on to describe how the results provided feedback and a better understanding of the flight configuration analysis model. (See Appendix T)

T. Jung (Fraunhofer Institute) asked whether a 0.65% adjustment in conductivity had really been necessary, because the conductivity was not usually known to this level of accuracy. He was surprised that such a small change had produced such a significant influence on the results. G. Baldan agreed that the influence was significant: they had not been able to monitor the wave guides directly because they had not had enough sensors and so they had used the sensors on the main shrouds. Therefore the combined effect was significant.

## 4.2. Open Source, component based simulation software development using Orcan

T. Jung (Fraunhofer Institute) described the need to replace an existing 2D axio-symmetric simulation tool with a true 3D version, and the decision to build a general purpose simulation framework from open source components as the foundation on which to develop the new version. (See Appendix U)

H. Rooijackers (ESA/ESTEC) asked whether the LASPACK software package was equivalent to the sparse matrix handling on LAPACK. T. Jung said that LASPACK was doing the same thing, but he did not know whether it was a derivative of LAPACK or whether it was a complete rewrite from scratch.

D. Gibson (ESA/ESTEC) asked whether the Orcan framework would be released under an open source licence, and whether the Open FOAM CFD library mentioned was also open source. T. Jung said that Orcan had been designed to be open source software, and indeed it was freely available from Source Forge. The Open FOAM library had been developed by a University College London spin-off company, but had been released under a Gnu Public Licence last year.

## 4.3. Workshop Close

H. Rooijackers (ESA/ESTEC) thanked everyone for coming, and gave particular thanks to those people who had prepared and given presentations. He presented apologies to the Wednesday afternoon presenters on behalf of O. Pin (ESA/ESTEC) for arranging a meeting in a parallel session and depriving them of a large section of their audience. He looked forward to seeing everyone at the next Workshop.

# Appendix A: Welcome and Introduction

## Welcome and Introduction

**H. Rooijackers**
ESA/ESTEC

# Appendix B: ESABASE/Debris Impact Analysis Tool

**Presentation**
**of the**
**PC version**
**of the**
**ESABASE/Debris Impact Analysis Tool**

**H. Sdunnus**
eta_max space

# Appendix C: Improvements in Thermica

**Review**
**of**
**Improvements**
**in**
**Thermica**

**T. Soriano**
EADS Astrium

# Appendix D: ESATAN Thermal Suite

**ESATAN**
**Thermal**
**Suite**

**H. Brouquet**
ALSTOM

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# Appendix E: Outcome of Harmonisation Activities

**Outcome of the**
**Harmonisation Activities**
**related to**
**space thermal engineering**
**analysis tools and methodologies**

**O. Pin**
ESA/ESTEC

# Appendix F: ESATAN-TMG

## A new tool<br>for the<br>Integration of ESATAN<br>with<br>FE based Thermo-elastic Analysis

**J. Thomas**
ALSTOM

# Appendix G: ThermNV Status

**ThermNV**
**Status**

**H. Brouquet**
ALSTOM

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# Appendix H: Monte Carlo Methods in TMG's Tools

## Integration of Monte Carlo Methods with TMG's Suite of Radiation Analysis Tools

**C. Jackson**
Maya HTT

# Appendix I: ESARAD Status

**ESARAD**
**Status**

**B. Castelli**
ALSTOM

# Appendix J: Radiative Software for Aero-Thermal Applications

## A Finite Element Radiative Heat Transfer Software for Internal and External Aero-Thermal Applications

**N. Lavery**
University of Wales, Swansea

# Appendix K: Interface between Patran/Thermal, Esarad and Thermica

## Interface Software Development
## for
## Patran/Thermal,
## Esarad, and
## Thermica

**C. Heller**
EADS Astrium

# Appendix L: Integrating FE Analysis into the Thermal Analysis Process

## Integrating
## Finite Element Analysis
## into the
## Spacecraft Thermal Analysis
## Process

**J. Etchells**
ESA/ESTEC

# Appendix M: Open Standards, Thermal Analysis, and STEP-TAS

**Open Standards,**
**Thermal Analysis,**
**and**
**STEP-TAS**

**HP. de Koning**
ESA/ESTEC

# Appendix N: AP203 to TAS Converter

**AP203 to TAS Converter:**
**A converter from AP203/AP214 to**
**STEP-TAS models,**
**based on**
**open source technologies**

**O. Pailles**
INCKA

# Appendix O: Baghera View Version 3

## Baghera View Version 3: the new version of the STEP based models viewer and synthesizer based on virtual reality and open source technologies

**E. Lebègue**
HANOP

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# Appendix P: Two Phase Capillary Loop Modelling with ECOSIMPRO

**Advances in**
**Two Phase**
**Capillary Loop Modelling**
**with**
**ECOSIMPRO**

**C. Gregori de la Malle**
IberEspacio

# Appendix Q: Thermica and Thermal Desktop Geometric Modelling

**Thermica**
**and**
**Thermal Desktop**
**Geometric Modelling:**
**a user perspective**

**A. Franzoso**
Carlo Gavazzi Space

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# Appendix R: Genetic Algorithms assisted ESATAN modelling at DLR

**Genetic Algorithms assisted ESATAN modelling**
**for automatic test verification**
**and other scientific use**
**of ESATAN modelling**
**at DLR Berlin**

**R. Nadalini**
DLR

# Appendix S: Thermal Model Reduction

## Thermal Model Reduction: algorithms and validation criteria

**M. Molina**
Carlo Gavazzi Space

# Appendix T: Verification of Planck LFI QM Instrument

## Thermal Model Verification
## of
## Planck LFI QM Instrument

**G. Baldan**
Alenia Spazio

# Appendix U: Open Source simulation software development using Orcan

**Open Source,**
**component based**
**simulation software development**
**using**
**Orcan**

**T, Jung**
Fraunhofer Institute

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# Appendix V: List of Participants

**List of Participants**

**19th European Workshop on**
**Thermal and ECLS Software**

**11-12 October 2005**
**ESTEC, Noordwijk, Netherlands**

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