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ABSTRACT

This document contains the minutes of the 16th European Thermal and ECLS Software Workshop held at ESTEC, Noordwijk, The Netherlands on the 22nd and 23rd October 2002. 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	2002-10-30	Document creation
1.1	2002-12-06	Partial draft for internal distribution
1.2	2003-01-24	Completed final discussion section
1.3	2003-03-18	Updated after internal comments

Table of Contents

Appendices

Final Programme

16th Thermal and ECLS Software Workshop
ESTEC, Noordwijk, The Netherlands
22nd-23rd October 2002

Tuesday 22nd October 2002

09:00	Registration
09:45	Welcome And Introduction C. Stroom, ESTEC/TOS-MCV
10:05	Thermal Modeling Issues Concerning the Mechanically Pumped Two-Phase Cooling for the AMS-02 Tracker A. Woering et al. NLR
10:25	SAVE: Simulation for Analysis and Validation of Energy for ATV R. Ameziane, EADS Launch Vehicles
10:45	Status of some ESA supported activities in thermal, thermo-hydraulic and ECLS analysis. O. Pin, ESTEC/TOS-MCV
11:05	Coffee break
11:20	Modelling the VISTA Infrared Camera N. Cavan, RAL
11:40	Thermal Analysis of Planck HFI J. Fereday, RAL
12:00	ESARAD v5.1 F. du Laurens d'Oiselay, Alstom Power Technology Centre
12:20	Application of EcosimPro to Bio-regenerative Life Support Components A. Rodriguez et al, ESTEC/TOS-MCV
12:40	ESATAN/FHTS v8.7 and v8.8 F. du Laurens d'Oiselay, Alstom Power Technology Centre
13:00	Lunch
14:00	Integrated thermal design and the thermal numerical toolbox J. van Es et al, NLR
14:20	Thermal simulation in functional analysis M. Jacquiau, Astrium-F
14:40	ALGOCAP: Assessment of Thermo Hydraulic Algorithms for Capillary Pumped Loops and Loop Heat Pipesl D. Labuhn, OHB-System
15:00	Use of ESARAD in MetOp SVM Thermal Testing Analysis E. Seward, Astrium-UK
15:20	Coffee break
15:35	ESA Harmonisation and User Survey HP. de Koning, ESTEC/TOS-MCV
16:05	Round Table Discussion
17:30	Social Gathering
20:00	Dinner

Wednesday 23rd October 2002

09:00	Use of TSS as a neutral format for geometry model conversions: an alternative to STEP-TAS H. Peabody, Swales Aerospace
09:30	CIGAL2: An open source pre/post-processing tool for CORATHERM and other software activities.. JP. Dudon, Alcatel
10:00	TMG: New Technologies and Modeling Approaches C. Ruel, Maya HTT
10:30	SYSTEMA/THERMICA version 4: Overview of the new capabilities M. Jacquiau, Astrium-F
11:00	Coffee break
11:30	ESATAN/FHTS and ESARAD: A View on the Near Future J. Thomas, Alstom Power Technology Centre
12:00	TASverter: Thermal Analysis for Space model converter S. Appel, ESTEC/TOS-MCV
12:30	ThermXL v2 and Beyond J. Thomas, Alstom Power Technology Centre
13:00	Lunch
14:00	ALTAN application for Bepi-Colombo thermal analysis V. Perotto, Alenia Spazio
14:30	Last developments in and around GAETAN C. Marechal, CNES
15:00	Coffee break
15:15	CAD-FE integration using Open Source Software C. Caillet, Open Cascade
15:45	Final discussion and conclusions
16:15	End of Workshop

1. Tuesday 22nd October: Morning Session

1.1. Welcome And Introduction

C. Stroom (ESTEC/TOS-MCV) explained that the main aim of the Workshop was to allow discussion of the tools sponsored by the Agency and to allow feedback between the users and the developers. (See Appendix A)

He had thought that this Workshop was one of the oldest run by the Agency but had subsequently discovered that the Antenna workshop was already in its 33rd year. He reminded everyone about the deadline for abstracts for the ICES conference in Canada in 2003.

1.2. Thermal Modelling Issues Concerning the Mechanically Pumped Two-Phase CO_2 Cooling for the AMS-2 Tracker

A. Woering (NLR) described the Alpha Magnetic Spectrometer payload which will be mounted on the exterior of the International Space Station. He then discussed the thermal control system and the various physical and software models which had been developed. (See Appendix B)

There were no questions.

1.3. SAVE: Simulation for Analysis and Validation of Energy for ATV

R. Ameziane (EADS-LV) presented the development of software for the management of energy systems on the ATV and its verification against the power requirements of the thermal control system. (See Appendix C)

R. Schlitt (OHB) asked whether there was software on the on-board computer for the control of the heat pipes, etc. R. Ameziane answered that the heat pipes and the power system were monitored by on-board software written in ADA in order to check that the thermal and electrical models matched.

O. Pin (ESTEC/TOS-MCV) asked whether the conversion from ESATAN to SABER involved any model reduction. He was told that there was no real reduction of the model itself but it was possible to compress radiative couplings if there were too many of them. O. Pin asked whether this was handled on a conductor or a node basis. R. Ameziane said that node reduction had to be done first in ESATAN because the ESATAN to SABER conversion only handled the reduction of radiative couplings.

1.4. Status of some ESA supported activities in thermal, thermo-hydraulic and ECLS analysis

O. Pin (ESTEC/TOS-MCV) briefly described various ESA initiatives which were already in progress, or which would start in the near future, relating to small tools, or to software not being presented specifically at the Workshop. (See Appendix D)

R. Schlitt (OHB) asked about the vision for the next five years, and whether this would involve merging some of the tools. C. Stroom (ESTEC/TOS-MCV) felt that this was an issue which should be dealt with during the round table discussions. O. Pin said that any vision within ESA still had to reflect the expectations of the real world and commercial interests.

M. Molina (Carlo Gavazzi Space) asked about the short term results. He felt that it would be a great year with so many things going on, and that it would be interesting to be kept up to date with developments twice per year. He wondered whether it would be possible to distribute such information via e-mail or via a news letter. C. Stroom agreed that this was a good idea.

1.5. Modelling the VISTA Infrared Camera

N. Cavan (RAL) described the requirements of the VISTA infrared camera to be installed at the European Southern Observatory, how ESARAD and ESATAN had been used for the analysis, and gave feedback on obvious improvements to the tools which would have aided the process. (See Appendix E)

H. Peabody (Swales) commented on the request for the tools to be able to handle optical properties which were dependent on the angle of incidence of incoming rays. He noted that many people seemed to want it, but wondered whether it was really necessary. He also wondered whether there was enough reliable angle of incident dependent optical property data. N. Cavan said that the optical engineers working on the RAL team certainly wanted it. They had already had some of the data and had made measurements to obtain more. HP. de Koning (ESTEC/TOS-MCV) reminded everyone that this was similar to the requirements of the Bepi-Colombo mission, for modelling albedo fluxes on some planets which exhibited BRDF[1] type reflection. He wanted to be able to handle such optical properties in a generic way in future versions of ESARAD.

C. Stroom (ESTEC/TOS-MCV) wondered about the comment made about the excessively high and the negative temperatures seen in the cryogenic parts of the ESATAN model. He thought that a specific routine had been provided for the cryogenic modelling of the ISO satellite. J. Thomas (Alstom) explained that the routines had been for calculating temperature dependent properties, and were not related to the solvers themselves. These conductance functions had been used at RAL. C. Stroom remarked that the automatic conductor generation should be discussed later.

F. du Laurens (Alstom) said that he [as the Alstom support desk manager] was aware of most of these issues. The automatic conductor generation, mission requirements and improved pointing would be presented the following day. The fact that ESATAN could calculate temperatures less than zero kelvin was related to there being no explicit check for this in ESATAN in order to avoid constraints on the solvers. The user could always provide a check for such temperatures in the $VARIABLES1 block. O. Pin (ESTEC/TOS-MCV) wondered whether this would simply invert the imbalance because of the radiation terms, i.e. $(+2K)^4 = 16$

1. Bidirectional Reflectance Distribution Function

and $(-2K)^4 = 16$. C. Stroom said that the $VARIABLES1 code only needed to check the temperature of specific nodes. J. Thomas agreed that there was a need to look into this to see exactly why ESATAN didn't check for negative temperatures.

HP. de Koning had a remark about having a node number increment of 10 between successive rings on the cylinder: the user could have a FOR loop in the geometry definition file to build the shells with the desired node numbers, rather than building them all individually.

1.6. Thermal Analysis of Planck HFI

J. Fereday (RAL) presented details of the Planck High Frequency Instrument, the extreme requirements for the thermal control of the cryogenic and detector systems, and the issues which had needed to be addressed during the modelling and analysis. (See Appendix F)

F. Lamela (EADS CASA) asked whether Fourier analysis in the frequency domain had been considered to compensate for the calculation noise in the cryogenic part of the model. J. Fereday answered that the Fast Fourier Transform facilities of Excel were applied to the output data. F. Lamela went on to ask about the temperature difference in the time domain. He said that there was numerical noise in the 6-8 digit precision results produced by ESATAN and that the FFT might filter this noise rather than the noise in the real temperature variation. J. Fereday admitted that this had been recognised as a problem, but it had not been addressed.

M. Molina (Carlo Gavazzi Space) asked about the frequency band for the cryogenic temperature variation. He was told that there was a wide range with the fastest being about 1/3 of a second mean variation and the slowest being about 1000 seconds. These varied across the different parts of the spacecraft. M. Molina felt that a common working group should be established by ESA to look into these problems. Thermal engineers were suffering frustration compared to the structural analysists because they didn't have thermal modes, eigenfunctions, etc. which could be applied. Engineers were trying to apply 2nd order derivatives to systems which didn't even have support for 1st order derivatives. In this particular case he felt that the basic values should be enough and because they didn't have a derivative. He wondered about applying band pass filters. J. Fereday said that the LFI team had been investigating such an approach.

1.7. ESARAD v-5.1

F. du Laurens (Alstom) outlined the new features which were now available in ESARAD version 5.1. This version had been released at the end of June 2002. He went on to describe some tips on how to make the best use of these features. (See Appendix G)

H. Peabody (Swales) asked whether the model tree would be expanded automatically when the user used the new search feature, and was told that it would.

A. Robson (Astrium Ltd.) observed that very big spacecraft models tended to be divided into both internal and external models each of which generated their own ESATAN files and required their own supporting code. He wanted to know whether the new integrated process would allow the user to import more than one set of ESARAD models into a single ESATAN model. J. Thomas (Alstom) said that this was possible: the analysis case definition allowed the user to specify any additional files which needed to be included in the ESATAN model. However, he warned that ESARAD couldn't check whether these included [ESATAN] files were correct. It was also possible to include external results as required. The analysis case template file only needed to be built once and then the ESATAN file could be regenerated every time using this template. Any external ESATAN or data files would be included automatically each time the ESATAN file was regenerated from the template.

1.8. Application of EcosimPro to Bio-regenerative Life Support Components

A. Rodriguez (ESTEC/TOS-MCT) described EcosimPro, a software package for modelling and simulating dynamic systems described by differential algebraic equations, ordinary differential equations and discrete events. He then presented the experience gained by using EcosimPro to model MELISSA[2], a closed loop microbial ecosystem. (See Appendix H)

There were no questions.

1.9. ESATAN/FHTS v8.7 & v8.8

ESATAN/FHTS version 8.7 was released in December 2001. F. du Laurens (Alstom) highlighted some outstanding issues with version 8.7, including the migration of licences from the old authorisation file scheme to the new FLEXlm licence system. He went on to describe the solver speed improvements and major new features of version 8.8, to be released shortly. (See Appendix I)

R. Schlitt (OHB) asked whether the solver improvements also related to two-phase systems in FHTS. J. Thomas (Alstom) said that there had been no mention of FHTS features because of the limited time for the presentation but a lot of work and feasibility studies relating to FHTS had been carried out in Alstom, with much work foreseen during the next year, especially in support of the @BUS platform. O. Pin (ESTEC/TOS-MCV) said that improvements had been made to the FGENFI solver to handle a fluid in pseudo-steady state. This had shown positive results in performance, but so far had only been implemented as a prototype. J. Thomas said that ESATAN/FHTS version 8.8 would handle absolute zero fluid flow, and more FHTS related changes were planned for future versions.

2. http://industry.esa.int/melissa/

2. Tuesday 9th October: Afternoon Session

2.1. Integrated thermal design and the thermal numerical tool box

J. van Es (NLR) presented the case for developing a simple thermal tool box for use in design studies, based on the experience of using ESATAN for several studies in the past. He provided some requirements for such an integrated tool. (See Appendix J)

M. Molina (Carlo Gavazzi Space) asked what kind of phase change material had been used for the design of the BIOFILTER experiment. J. van Es said that the material had been a type of paraffin, with an Alpha number of “ADK something”, but he would really need to look it up. The phase change occurred at 5.9^{o}C. A. Rodriguez (ESTEC/TOS-MCT) asked whether the hysteresis of the melting point of the phase change material had been taken into account. He was told that the hysteresis had not been included in the model itself, but it had been accounted for as a safety factor in the design margins.

C. Stroom (ESTEC/TOS-MCV) wanted to know whether the MLI had been used in vacuum in the BIOFILTER experiment. J. van Es said that it was possible to experience problems in obtaining correct results when using MLI inside a pressurised box. The results could always be calculated for MLI in vacuum. He agreed that the vacuum was important.

C. Stroom remarked that the Open Source Software aspect of such a tool box should be asked during the round table discussion,

2.2. Thermal simulation in functional analysis

M. Jacquiau (Astrium SAS) described some of the areas where functional analysis required some level of thermal simulation, and the small tools and interfaces which had been developed to integrate them. (See Appendix K)

J. Persson (ESTEC/MSM-MCS) asked what was the difference between the power software tool and that described earlier by EADS. JP. Hulier (EADS LV) said that their software was intended for use in the pre-design analysis. M. Jacquiau said that their software was used in the preliminary design and also in the detailed design of some sub-systems. He admitted that it was similar to the EADS approach and worked with a description of the network. JP. Hulier wanted to confirm his understanding that the Astrium software was limited to 40-50 nodes. M. Jacquiau admitted that the CAT software was limited to 40-50 nodes. The solver being used was ESACAP. However, the Propulsion software used a different solver and also made use of components build by the user. JP. Hulier commented that this was a difference between the system and technological approaches.

2.3. ALGOCAP: Assessment of Thermo Hydraulic Algorithms for Capillary Pumped Loops and Loop Heat Pipes

D. Labuhn (OHB) presented the current results of an investigation into the application of capillary pumped loops and loop heat pipes in spacecraft thermal control systems, and the issues encountered when trying to simulate such components using some of the current software tools. (See Appendix L)

There were no questions.

2.4. Use of ESARAD in MetOp SVM Thermal Testing Analysis

E. Seward (Astrium Ltd.) described how ESARAD 3.2.7 had originally been used for the analysis of the test configuration of the MetOp SVM in the SIMLES chamber and the problems which had been encountered. She went on to explain how the model had been updated to work with ESARAD 4.2.10, which problems had been resolved and which still remained. (See Appendix M)

HP. de Koning (ESTEC/TOS-MCV) was interested to know whether the problems with the transmissive surface used for modelling the chamber mirror were related to the use of diffuse rather than direct transmission. A. Robson (Astrium Ltd.) felt that they were related to the Monte Carlo method being used. HP. de Koning explained that ESARAD only supported diffuse transmission so this needed to be taken into account when modelling.

D. Gibson (ESTEC/TOS-MCV) commented that although Astrium had experienced problems with the correct positioning of user oriented parts of the model during animation via the GUI, it was possible but required working directly in the ESARAD language and applying some tricks[3].

2.5. ESA Harmonisation and User Survey

HP. de Koning (ESTEC/TOS-MCV) presented details of a harmonisation strategy being developed within ESA in order to provide better integration of tools and data across various disciplines relating to different space environments. He also described the results of a user survey which had asked users about their preferred options for such a harmonisation strategy, ranging from proprietary commercial systems to open source software, and from centrally coordinated development to a market driven approach. (See Appendix N)

Questions were deferred until the following round table discussion.

2.6. Round Table Discussion

C. Stroom (ESTEC/TOS-MCV) asked who wanted to start the discussion. He suggested starting with the issue of Open Source Software (OSS).

J. van Es (NLR) said that the success of OSS depended on the size of the active group of developers. He had seen examples where it had worked, and the product had improved because it became the storage for the knowledge of the contributors. He felt that ESARAD and

3. An example model and language files were sent to Astrium after the Workshop.

ESATAN tended to be used by “now and then” users, so using OSS to store knowledge could be important. He wanted to know how big the ESA software user base was. C. Stroom asked what he considered as examples of success. J. van Es said that the problem [with the space thermal community] was that the group was small, and that most of the companies within the group competed with each other. He was afraid that people wouldn’t share their knowledge. C. Stroom said that he really wanted as many users as possible to be involved in developing a generic, core tool kit, especially in this common area where companies could not claim to be in competition. J. van Es agreed in principle, but was not sure that a large company which spent money on a GUI for their people would be happy to share that effort. He said that many such users had their own tools which interfaced to ESATAN.

R. Schlitt (OHB) wondered whether OSS was really the future for software development. He felt that the first option [“hands off” approach with little coordination or harmonisation] would not be possible with OSS. C. Stroom said that the first option meant that ESA would not need to do anything. R. Schlitt asked whether a management board to support the second option [“harmonised” approach with coordination for the development of generic tool kit components] would include user representatives as well as ESA. C. Stroom said that one of the outcomes of the user survey had been that users felt that developers should not be in such a management board. F. du Laurens (Alstom) asked how the developers had responded to the survey. C. Stroom said that the problem was that they felt that they should be on such a board. He added that it could be that users felt that they had little influence on the current software development, and that restricting the membership of the board to users could provide the opportunity to change this. C. Stroom said that there was a balance between what software and features the users actually wanted to be developed, and how this development could be paid for. The available resources usually limited the choices. He felt that priorities [for feature development] should be given by the users, but the users were not usually in a position to determine how much the development would cost. Therefore it would be necessary to include the developers in the management board, but maybe they should not be able to vote on the priorities.

C. Stroom asked the audience whether people really wanted to share. He felt that there was such a large block of common functionality which everyone needed. He asked whether companies who had software which addressed this common functionality would be prepared to contribute it to help in building a common system. C. Ruel (Maya HTT) said that there was not enough money in such software to influence commercial companies. Users expected OSS to be free. Current software typically cost 1-10kEuro to produce, but this was a lot for “free” software. He didn’t feel that commercial companies had much incentive in providing “free” software.

C. Ruel wondered about the stability of the OSS code base. The infrastructure to allow users to incorporate changes into the code base would not work in the commercial environment used at Maya. C. Stroom said that there were different models which could be used, and gave the Linux kernel as an example. All changes were submitted to a central authority where they could be tested, validated and placed under configuration control. Another example was Apache, where the user downloaded the source, typed “configure” and could then build and install the software.

C. Ruel asked whether testing could be embedded in OSS thermal tools. C. Stroom said that testing would need to be included, because the community could not afford complete anarchy. He envisaged a system where ESA would handle the version control and testing via a central repository and users would be able to download the source code. All users would have access to the release versions of the tools, such as “esakit-8.7” as well as any of the development versions. Any additional development by a particular user should be sent back to ESA, and there could be a vote on whether further resources needed to be spent to improve the quality of the changed or additional code before its integration into the repository.

C. Stroom commented that one of the findings from the survey was that code needed to be validated on both quality and robustness, so some scheme needed to be put in place to provide the means for producing robust, functional software. C. Ruel was concerned that if code was being received from many people, wasn’t there the risk that a lot of time and effort would be spent on evaluating all of the changes, deciding whether they were compatible with the existing code, etc. and wondered whether it would be easier to start code development from scratch. He asked whether this would prove to be an impediment to the development of new code, when so much effort would be spent on new code, and a lot of effort to evaluate the code, and in the end a lot of code being discarded or needing to be reworked before it could be integrated in the central code. C. Stroom argued that there would be overall cost reduction in avoiding duplication of code in all of the different tools currently being maintained, and that producing common software would not necessarily be cheaper than the cost of a single company producing its own tool. It should also be faster to redistribute the common software to the users as the development version would be available as well as the last released version. If a specific need arose for a specific project, that project could always clone the software in order to develop the features that it needed.

C. Stroom returned to the question of money. He said that some resources would be needed to start such a project. The figure of 1-10kEuro would not really cover development, but he felt that the cost of software maintenance would probably prove to be more of a problem. Commercial software vendors always had to consider maintenance. He said that the business model for moving to OSS development would also need to address the long term running and maintenance of the software. He emphasized that the cost of maintenance of software went up as the software grew older. He gave the example that ESATAN was already 20 years old, and it would need to be maintained for another 10 years before it could be replaced. J. Thomas (Alstom) was quick to point out that any replacement for ESATAN did not necessarily have to be an OSS version. C. Stroom agreed, but said that ESATAN was in need of an overhaul, but it was not clear how this should be achieved.

F. Lamela (EADS CASA) wondered about the French position on OSS development. He had experience with a Belgian company called SamTech developing a “new NASTRAN”. This new software was being used by many French companies, so he wondered whether there was a requirement to use this particular software. He wanted to know what other companies were doing who were currently using NASTRAN. He said that the “new NASTRAN” users wouldn’t see details of the meshing and surface properties: they would see a CATIA view only, and then produce data for import into Excel. This was one software product aimed at a specific manufacturing application where the user did not need to know anything about the internals of the calculations. HP. de Koning (ESTEC/TOS-MCV) confirmed that SAMCEF was the only real competitor to NASTRAN in Europe, and that it was used a lot in the non-linear domain. There were other OSS projects in Europe, such as OpenCASCADE. SAMCEF used this OSS internally, e.g. to provide the geometric engine. He went on to say that everyone had to take the French position to be that given by the French delegation to ESA. HP. de Koning stressed that there was also a large difference between the provision of software for the structural and thermal areas. NASTRAN type tools commanded a huge market involving tens of thousands of seats, but the thermal tools had a much smaller market.

HP. de Koning felt that the second point which F. Lamela had made, that of hiding the details of model construction and calculation, would be more difficult to achieve. It wasn't always possible to rely on "point and shoot" type software systems: the users had to think about how to achieve what they wanted, what assumptions were made by the tools, etc. Users needed to have access to the details in order to perform verification of models. He agreed that people were more exposed to the internal workings of software than they should or needed to be, but access to the internals was still required for parametric studies, etc. There was a need for a scripting interface to many tools in order to get at the internals. He had big doubts that "point and click" systems would suffer from the limitation imposed by lack of user access to the internals.

F. Lamela argued that most structural engineers were only interested in the spacecraft as a series of panels. The user passed the length of both sides of the panels to CATIA, the panel could be meshed automatically, etc. He suggested that five parameters could be used to represent most thermal models. The user should only have to provide the software with these parameters in order to get a result. The meshing and calculation could all be hidden inside the software. For example the user should only need to give the diameter of a hole in a panel for the software to be able to produce the results in the GUI, or to be able to generate reports automatically. HP. de Koning said that this related to the automatic idealisation of the model and the extraction of the results from the model. Engineers could use procedures to advantage for achieving this. NASTRAN could afford to offer these features because of the large user community, but it was difficult for companies to justify spending the effort to achieve this if there were only a hundred users of their tool.

C. Ruel was worried that if people were able to download the source code, they could always develop their own GUIs or enhancements if they didn't like what the central version offered, and that this would lead to the existence of incompatible versions. This is what had happened to other tools, such as SINDA, and the different versions tended to grow. HP. de Koning agreed that this was an argument against distributing source code. He said that ESATAN could have been distributed with source code, but by not doing so any differences between the various sites running ESATAN had been avoided. With OSS, a different approach had developed over the last 4 or 5 years, and that this was based on trust. The idea was that if you participated in the software development along with others, then you would get back more than you put in. However, if people hijacked the development for their own ends, there was the risk that chaos might ensue, but in practice the development community would not tolerate this. C. Ruel asked how the situation could be policed effectively. C. Stroom answered that it usually came down to self control. He had access to the sources for the Linux kernel, and in theory could modify them for his own needs, but so far he hadn't been tempted to do so. Anyone who did make changes outside the main development stream usually found that the next upgrade couldn't be applied without re-modifying the new sources to reflect the user's own changes, and that this soon became prohibitive.

C. Stroom felt that 20 years previously the thermal software community had been amateurs when it came to software development. A lot of experience had been gained over that time, and the situation was now different. Maintaining software was a costly business and now everyone realized this. He was sure that all of the companies represented at the workshop realized this.

However, most of the people at the workshop didn't come from software companies. All they wanted were tools to help the thermal design process. Most people used the tools as they were, and only if they needed a specific feature would they even consider writing code of their own. He felt that people simply didn't have the time or money to dedicate to writing such code. HP. de Koning commented that the growth of the Internet and Web technologies had enabled easy cooperation between different groups no matter where they were in the world. This was very different from 20 years ago when sharing programs and data involved sending tapes, lengthy delays, etc. C. Stroom repeated that chaos could only result if there were users who forked their own versions of the software.

C. Ruel said that TMG had hundreds and thousands of customers and not just in the aerospace sector, so they had lots of requirements from different parts of the market. C. Stroom observed that even large companies had disappeared. Look at EUCLID and ASKA. However the engineers still required tools in order to make satellites. C. Ruel said that Maya had funding from the Canadian Space Agency and the intellectual property rights (IPR) of all code developed for the CSA was shared. If Maya went out of business, then the CSA would have access to the source code. C. Stroom admitted that this was true in theory, but said that if a company such as Maya or Alstom disappeared then the concentration of all of that company's knowledge would disappear too. R. Schlitt suggested that ESATAN and ESARAD could be marketed along with NASTRAN. J. Thomas (Alstom) said that they had probed MSC about this in the past, but that MSC hadn't shown any interest in doing so.

C. Stroom was under the impression that users didn't want to have a list of prescribed tools. HP. de Koning agreed and said that stability needed to come from the provision of good interfaces. Different tools could then use those interfaces. He said that the standardising on particular tools had never worked.

F. Lamela introduced the differences between working in the commercial and the scientific satellite markets. Their @BUS work provided for 200 hours to be spent in England and 100 hours to be spent in Germany, and such pressure would not leave them with enough time to write a report on the results obtained. He said that tools must introduce minimum cost to the engineering process. The time taken to discretize a model need to be reasonable, but this was an area which needed to be fixed in software. He felt that there were issues of innovation and communication. He felt that there wasn't enough communication about the existing developments in the standard software and was worried about how this would work with innovative software being developed as OSS. If he needed to add functionality to such innovative software, how would he be able to discover whether someone else was already working on it? He said that most companies didn't give away information.

F. Lamela was also interested to know how people could manage the cases of low prices and tight schedules which were normally presented in proposals. For example, he was interested in good software to help in the calculation of antenna characteristics. However, structural engineers took one week to calculate what they needed whereas the thermal people took three months. C. Stroom asked whether F. Lamela wanted a marketing tool or an analysis tool. Was he really interested in a tool to help in winning bids? Was he looking for a nice tool which could provide approximate results quickly but which would not be reliable for detailed models? C. Stroom explained that he had visited JPL, where there was a CDF[4]. Engineers from all disciplines sat together in the CDF to make the design for a new satellite. All NASA sites competed on bidding for the satellite as part of a competitive ITT. The successful bid came from JPL, with the CDF. However, the question then arose of what to do once the bid had been won. Should JPL continue with the design which had been produced by the CDF for the bid? In fact, the CDF had been used to produce a design specifically to win the bid. Once it had been won, this design was discarded and the real design started again. C. Stroom felt that if the goal of the tool was to be able to convince the marketing manager that a radiator would need to be 300kg and handle 300W then this was fine. However, it was important to know the level which the users expected for this tool.

R. Schlitt said that the important word which had been mentioned during the discussion was “communication”. He was in favour of the harmonisation meetings, but stressed that it was important to have user involvement at the beginning of any development work. He felt that it was necessary to have users take part in more discussions. He suggested two meetings per year. However he recognised the problems involved in organising such meetings. He already had a problem of how to discuss loop heat pipe technology with software developers and users when there was no spare money to enable such meetings. He went back to the communication issue and said that every year there was a new version of the software and users were not always fully aware of the new features and improvements. C. Stroom agreed that communication was important and that there should be users and ESA representatives on any software management board, but he wanted ideas on exactly how this should be achieved. Yes, there were the yearly meetings and other things which would be of interest to users. Users also had their own “wish lists” for new features, but usually they had no time to communicate these requirements when they needed them most. C. Stroom felt that it would take more than just a news letter to keep them informed of all new developments. R. Schlitt admitted that they had problems with software, but they never saw some of the developers (e.g. Alstom) in order to discuss solving them, whereas some other developers visited regularly.

C. Stroom said that the space thermal tools had only about 10% of the market compared to some other tools, and had only a small budget for development and maintenance. Therefore it was necessary to know how to prioritise in order to make best use of the budget. R. Schlitt thought that there must be a lot of money around if all tools such as THERMICA, CORATHERM, etc. were taken into account. What was needed was some way of harmonising the money spent on the different tools. HP. de Koning stressed that this was the whole point. In Europe the user community was too small to warrant so many parallel tools and developments. He felt that in the future, Europe would need to pool all of these resources together.

C. Stroom wondered whether there was a need to pay users for their rôle in requirements gathering, ECSS involvement, etc. All users seemed to want data exchange, but none of them had the time or money to be able to contribute to defining the requirements. H. Peabody (Swales) felt that the funding was key to the development process, and said that a company would drive development as long as there was a task to be completed and a need to have a new software feature in order to complete that task. However, if there was no clear project or task to which such development could be charged then the company was unlikely to pay. It wasn’t always possible for developers to work on what they wanted to work on. He went on to say that the idea of OSS was great, but if the users didn’t have the time or resources to put into the development, then it wouldn’t work. C. Stroom admitted that this was true to a certain extent.

4. Concurrent Design Facility

The Apache model for OSS development wouldn't work for the space thermal community. H. Peabody argued that Apache had a lot of users in comparison to the thermal community. HP. de Koning commented that OSS didn't necessarily mean free of charge. H. Peabody admitted this, but countered by saying that if his company wouldn't pay [his time and resources] then how could he contribute to any OSS development. C. Ruel felt that this was a key point: a developer needed resources in order to work. C. Stroom argued that since people were already developing a lot of tools on their own, these resources were available, but were not coordinated. He said that a lot of components were already available as OSS: there were systems for ray-tracing, scripting, etc. HP. de Koning said that a lot of OSS development was about gluing existing components together rather than developing everything from scratch. C. Stroom said that without being able to work in terms of smaller components, any changes to software required a major overhaul of the code. Rewriting a system such as ESATAN or ESARAD was not really a development problem, but more of a maintenance problem in the long term.

C. Ruel wondered whether it would be possible to issue contracts to maintain OSS code. HP. de Koning said that there were different models available for developing and maintaining software. People could pay to join a board which oversaw any development work, or people could buy services which could pay for development. Therefore issuing contracts to maintain code was a serious possibility.

J. van Es was concerned about the issues of giving any software away. He wondered whether it would be possible for ESA to sub-contract thermal analysis and then provide a bonus if any tools developed by the company were contributed to the common software base. In the future, people should be encouraged to generate tools for the common software base as part of project work. C. Stroom commented that this was basically what HP. de Koning had said: the company should pay for development, and then contribute it to the community for the common good. H. Peabody didn't think that it would be as easy as that. It had taken him four years to develop ThermPlot but Swales owned it, Goddard had some rights to it. He was not the owner.

C. Stroom observed that the discussion seemed to have become stuck on OSS, and wondered whether there were any other topics.

E. Werling (CNES) asked about using SYSTEMA as a solution to the common software base. HP. de Koning admitted that SYSTEMA and THERMICA formed one of the major tool kits. However it was a good example of what was meant by duplicate effort. It would be better if all effort could be brought together in the interests of the user community as a whole in order to provide common tools.

E. Werling observed that the Harmonisation report had mentioned a user group with ESA responsibility and wondered what form this would take. HP. de Koning answered that there was no real name for such a group. E. Werling asked whether anything had already been planned. HP. de Koning said that it could be that one of the recommendations to be made in the Harmonisation road map would be to form such a group, There would be a meeting in the middle of December to consider the options. L. Maresi (ESTEC/IMT-THH) said that, provided some consensus could be reached, information from the Workshop could be used to help with the recommendations to the meeting in December for the development of a common tool kit. C. Stroom said that ESA had to deliver the documents one month before the meeting, so time was tight.

R. Schlitt commented that the “tool kit” under discussion was currently without form and it was necessary to define what was actually wanted or needed, what primitives should be provided, etc. C. Stroom asked who would be prepared to participate, and he meant really participate rather than just provide vague support.

S. Dolce (ESTEC/TOS-MCT) was prepared to give an example where in a project, if the phase A/B design suggested the use of Loop Heat Pipes [LHP] using ESATAN/FHTS, if nothing was already available on the market then the project would consider developing its own. He felt that it would be a good idea to have a list of desired technologies to be supported, and that this list should be made public so that users could contribute and be involved in the decision making. At the ESA level such a list would show whether there was a need for ESATAN-II, and ESA would know that they would have to make it available. The same held true for the harmonisation group, or for French companies: if they needed LHP technology support, they needed to go through the same process. If it was not possible to have such a scheme to help direct common development, then model exchange between the different tools would be essential. HP. de Koning agreed, but said that the data exchange was an independent issue. S. Dolce argued that data exchange had been discussed for years, but projects weren’t prepared to wait five years for an ideal solution: they needed solutions now, and were prepared to develop their own if necessary.

J. Thomas informed everybody that ALSTOM maintained just such a list of Feature Requests on its web site, although access to it was restricted for a variety of reasons. These Feature Requests had been produced after discussions with customers, or from comments during previous workshops, etc. He said that he had collected two pages of Feature Requests from this Workshop alone! He wondered whether there was enough interest to make the Feature Request List available to a wider public, although he said that there were some aspects of confidentiality, etc. which would need to be discussed. He went on to say that ALSTOM had adopted the policy that development work should be 100% driven by the direct project requirements or by items on the Feature Request List. Therefore, developments shouldn’t really be a surprise to the users. He wondered whether even more transparency was needed in order to improve the requirements process.

S. Dolce felt that there had to be some link between the needs of the users and projects and the way of reacting to them quickly. J. Thomas said that there were some differences between general user requirements and specific project requirements, and it was necessary to balance the two. If a particular feature request would only be useful to one or two companies than it would be hard to justify doing the development with general development money. However, Alstom were open to discussing requirements with any company or project which had specific needs and which was prepared to pay for their implementation.

S. Dolce wondered whether the drawback to the current proposal was that until some consensus was reached by the delegation it would be difficult to make any progress. HP. de Koning argued that trying to prioritise Feature Requests at the European level would be valid for all products. He felt that there was a need to do this across the community and not just at the vendor level. He admitted that there was a certain level of commercial conflict of interest. He stressed that people who shared the common environment needed to put things into it as well as get the benefits out of it. The question was how to do this without exchanging software. A request for a new feature to be added to ESARAD would probably apply to THERMICA as well. The difference between the commercial approach and the harmonised approach meant that different groups would gain from each. The question was how to find a middle ground in which all parties can benefit.

M. Heuts (Dutch Space) asked what the users were actually interested in. Most companies were interested in tools which enabled the engineers to work in an efficient manner, and it didn't really matter which tool that was. Dutch Space wouldn't invest in tools if it could work with existing tools. He agreed with the harmonisation effort if the goal was to work efficiently, but if he needed to spend lots of money in order to participate, then he wouldn't take part because at the moment he could work with the existing tools. C. Stroom forecast that the current situation which had existed for twenty years wouldn't continue for another twenty. Therefore there was a need to do something before current expertise was lost. For example, ESATAN had been written using F77 and in the future there would be fewer developers with experience of F77, and less support from vendors. The aim of the harmonisation wasn't for the short term, but looking to the three to five year time frame. M. Heuts said that he would be prepared to participate on a part-time basis to help achieve such a goal.

P. van Leijenhorst (Dutch Space) said that it was necessary to ensure that the effort went in the right direction. Participation should not necessarily involve paying, but it would mean that there would be a better consensus in how to use the R&D money, and more people to help convince the delegates about what was needed. C. Stroom said that participation would take time and that "Time is Money". He said that a set of crosses on a list or survey wasn't enough to build consensus. He knew that the user community had a wide range of varying opinions, and that it would be necessary to find the common goals and requirements of the users. He stressed that if the users were not involved in making the decisions, they would probably be unhappy with some of the results which came out of them.

H. Peabody felt that it would be beneficial for users if someone could provide a web site where users could store information on new technologies, LHP, software requirements, etc. He compared this with the Visual Basic bulletin board, where users could search a knowledge base for answers to their own questions. C. Stroom agreed that these were valuable suggestions, and something like this had been envisaged for the now-defunct Thermal Mailing List. H. Peabody said the difference was that the information needed to be searchable. C. Stroom wondered about effort required to keep such a web site up to date. H. Peabody said that there must be a lot of people who had home grown software that nobody else ever found out about.

C. Marechal (CNES) reminded everyone about the GAETAN development. At the beginning the users had been involved in the requirements and design, but had only contributed financially when they had been obliged to, such as when the software was changed for them, or when the users had new needs which the software didn't meet. There had been user group meetings every two months to allow for feedback, but these had collapsed after only three meetings because the software worked to do what they wanted. C. Stroom admitted that there had been a similar experience with an ESA software board which had met four times and then hadn't really worked any more. What he had learned was that user involvement really needed to be set up differently. This was what a suitable web site might be able to offer. People rarely had spare time and resources so the number of physical meetings could be reduced, having them as additional sessions within workshops for example. He felt that it was important to use the user interest more efficiently.

E. Werling remarked that there was a document - a strategy paper by ESA - which could be sent to industry for comment. C. Stroom pointed to the ECSS web site where it was possible for a user to be sent notification when a document had been added to the web site. HP. de Koning said that there was already an initial version of a Thermal web site, and he wanted to build on this site to provide a discussion forum.

R. Schlitt said that as far as user involvement was concerned, if the users could see that they would save time and money by using new developments in the software, and being able to guide those developments, then the users would be more interested. He said that he often saw RFQ and ITT documents but he didn't usually know how such initiatives would affect him directly.

C. Stroom said that he wanted to make a form of business case for any new form of development. He felt that there should be real milestones, and if these were not reached then the development should be abandoned, but it was important that the whole community should make this business case together. Everyone in the user survey had said that ESA should take the lead, but he felt that users still needed to participate. HP. de Koning said that the December delegation would comment on any proposals, so users should ensure that the delegates were aware of their positions.

V. Perotto (Alenia) observed that the current situation had been created by a number of boundary conditions. One of these was the lack of confidence of the users in the developers and ESA in providing software to address users needs. He gave the specific example of lack of progress on the data exchange problem. He felt that if he could present something to his management or to the delegation that something was actually being done, then he might be able to change their attitudes.

HP. de Koning remarked that the data exchange question would be handled during a presentation on the following day. V. Perotto had already heard about the initiative to provide conversion between ESARAD and THERMICA, and he could inform his management that things were moving again. If his management could be convinced that ESA could provide results within six months, then they could use their own resources and effort in a more efficient way. HP. de Koning said that ESA had already taken measures to ensure progress on data exchange. ESA had taken responsibility for developing the converters. An alpha version was already available, and he was hoping to be able to distribute the converters free of charge before Christmas.

V. Perotto went back to considering the problems of selling a common tool kit to management. He said that a user might want to present a bit of an existing tool to ESA as part of the common tool kit, but it might be difficult to obtain management authorisation to do so. If users were allowed to participate, what would each company offer? He felt that authorisation would be hard to get because it wasn't clear whether the company would actually get any compensation for the effort.

H. Peabody said that it would be helpful to know exactly what tools were already being used. There might be a problem of actually distributing existing tools, but it was often useful to know that a particular tool was out there. C. Stroom agreed. He said that collecting such information depended on the amount of available ESA manpower, and he admitted that maybe ESA should do more.

A. Crutcher (FSC Ltd.) gave a developer's perspective on user involvement. As the ThermXL developer, they had offered two seminars to end users to discuss requirement and development, but in the end only one person had been interested. He felt that end user involvement had to be simple to use, such as a Web based discussion board. However, he was not entirely convinced about end-user involvement in general. What currently happened was that ESA funded some development and at the end of it the users criticized the result, but he felt that this might be the only way of working because "design by committee" was rarely successful. He felt that there should be a small executive committee which should put forward ideas, try to deliver these to the users, and take any criticism

A. Crutcher admitted that the OSS idea sounded quite good but gave Red Hat Linux as an example of a value added OSS product which had to be bought even though the component parts could be downloaded for free elsewhere. HP. de Koning felt that this model was fine if people were prepared to pay for additional services or maintenance. A. Crutcher emphasised that OSS systems were inherently different to packages such as EcosimPro. He felt that many end-users would have difficulties to build all of the tools from scratch, or to incorporate ray tracers, etc. and that they wouldn't all be able to put all of the components together. HP. de Koning admitted that this was true: end-users wouldn't necessarily be able to build the tools because it really needed to be done by software engineers. However, he said that there were examples of such systems out there, and gave OpenCASCADE as an example of a large OSS system with many contributors.

C .Caillet (OpenCASCADE) explained that there had been 18 Meuro of investment in the OpenCASCADE system, initially by Matra Datavision, before it had been converted to an open source system under the control of a daughter company. This company now sold services in software engineering on how to use the open source software. The business model had been built entirely on these services. The services included integration and technical support provided to customers.The sale of these services provided the money needed to improve the product, investment in research and development and extending the platform base. Some funding also came from European and French research initiatives. There would be a presentation on the SALOME system the next day: this was an integration of CAD with numerical simulation. Nine partners had spent 540 man years in its development. He agreed that maintenance of software cost a lot and that it was a big issue. The company had to ensure that there was an on-going customer maintenance project with general bug fixing for the whole community, and a system of charging customers with support contracts for fixing specific bugs rapidly to enable them to continue working. This resulted in a sharing of costs and benefit across the whole user community.

R. Schlitt returned to the issue of user involvement: he said that the software developer had to convince the customer to buy a particular software product. A. Crutcher wondered what would happen if a company offered software as OSS, what terms and conditions would apply, and whether these would apply worldwide. HP. de Koning said that the software could be restricted to a user community group. C. Stroom commented that there were already systems available with restricted access, such as the various environment models developed for SPENVIS[5]. However, he didn't know how the different access models to the common tool kit would work in practice.

5. Space Environment Information System. See http://www.spenvis.oma.be/spenvis/

3. Wednesday 23rd October: Morning Session

3.1. Use of TSS as a neutral format for geometry model conversions: an alternative to STEP-TAS

H. Peabody (Swales) presented the problems of trying to share model data with different project groups and the different software systems which they use. With no current consensus on a common format for data exchange between tools, and with TSS providing a superset of the facilities available in other tools, he had produced a series of converters for translating models to and from the TSS format. He described the additional conversion tricks which were required. (See Appendix O)

N. Cavan (RAL) asked whether the conversion process conserved any model hierarchy and was told that it did. H. Peabody said that ESARAD reported everything using global coordinates whereas TSS used staged coordinate systems. The ESARAD converter had been written first, and it should really be revisited to apply the knowledge gained writing the other converters. The converter had an option for trimming surface names, but this could result in a problem of nesting in ESARAD, so the software had to keep track of all trimmed names.

J. Persson (ESTEC/MSM-MCS) asked whether TSS would become the replacement for TRASYS. He was interested to know whether a TSS model of the International Space Station existed. H. Peabody said that TSS had been designed as the replacement for TRASYS. He didn't know why NASA had chosen TRASYS to model the ISS because he knew that NASA converted the model to TSS in order to view it. The conversion from TSS to TRASYS and back was a simple one. J. Persson wondered whether it would be possible to use the ISS model in TSS and convert it to ESARAD. H. Peabody said that it was probably possible although he hadn't tried it.

C. Stroom (ESTEC/TOS-MCV) referred back to the viewgraph on the neutral formats and said that TSS was effectively proprietary software and therefore could not be controlled. This was one of the arguments for a true neutral format. H. Peabody admitted that the TSS format could be changed without warning, but so far it had proved to be very stable. C. Stroom felt that import and export should really be handled by the tool supplier, and not by reverse engineering the required data formats. However, he admitted that the TSS converters worked, and European efforts to work with STEP-TAS were still incomplete.

3.2. CIGAL2: An open source pre/post-processing tool for CORATHERM and other software activities

JP. Dudon (Alcatel) described the userof CORATHERM in Cannes, and the design of a new tool, CIGAL2, based on open source components to integrate the various pre- and post-processing needs of the thermal engineers. (See Appendix P)

S. Appel (ESTEC/TOS-MCV) asked whether he had understood the last slide correctly to mean that some interpolation was needed to map thermal node temperatures to the finite element nodes. JP. Dudon said that this was only necessary to fit the meshing and that when the finite element node corresponded to the finite difference node the thermal calculations on the finite difference meshing could use EQUIVALE. S. Appel said that this implied that the system used the finite difference conduction matrix on the finite element nodes. JP. Dudon agreed and said that finite difference tools were used to calculate local temperatures on small nodes and these were then used for the final temperatures of the finite element mesh. S. Appel said that with an initial fine lumped parameter mesh and a final finite element mesh it would be easier to make a mapping. JP. Dudon agreed that such an approach would make it easier to get the final mapping.

HP. de Koning (ESTEC/TOS-MCV) noted that the example had achieved $\pm 2^{o}$ accuracy in the condensed model compared with the full main model. He asked whether there had been a similar check on the heat balances if nodes were grouped. T. Basset (Alcatel) said that it had. HP. de Koning said that it would be useful to have an indication of the accuracy and constraints of the reduced model. JP. Dudon replied that this would be a parameter which would be taken into account in the future.

E. Werling (CNES) suggested that the a STEP-TAS converter needed to be added to the framework. JP. Dudon admitted that it was already in the planning. E. Werling said that this was important, because it would enable communication and interchange with other tools such as THERMICA and ESARAD.

3.3. TMG: New Technologies and Modelling Approaches

C. Ruel (Maya HTT) presented a comprehensive overview of the capabilities of TMG, outlined some of the algorithms being used, and described some new features which would be available in the next release. (See Appendix Q)

H. Peabody (Swales) asked when the new version would be available. C. Ruel said that IDEAS-10 would be released at the beginning of 2003, but some of the features which he had described were already available in IDEAS-9. HP. de Koning (ESTEC/TOS-MCV) asked whether these features would be available in both FEMAP-TMG and IDEAS-TMG and was told that they would.

3.4. SYSTEMA/THERMICA version 4: overview of the new capabilities

M. Jacquiau (Astrium SAS) described the current capabilities of the SYSTEMA framework, and detailed the latest developments within THERMICA and related applications. (See Appendix R)

C. Ruel (Maya HTT) asked about the tolerance used for the automatic detection of contact between shells. M. Jacquiau said that the user could tune the tolerance value used during the detection of contact between edges. C. Ruel wanted to know whether the user could specify the contact resistance. M. Jacquiau answered that the contact resistance could be given by the user.

H. Peabody (Swales) asked whether THERMICA could handle surfaces with thermal nodes on both sides. M. Jacquiau said that he hoped to be able to offer this in the future, but for the moment it was still necessary to use two surfaces, one for each node.

E. Werling (CNES) asked whether the full SYSTEMA suite would be offered as a commercial package. M. Jacquiau said that a decision would be taken soon. He explained that some specific applications were already available commercially, but the complete framework was different. It was easy to exchange data models between the different applications within SYSTEMA. He wanted to commercialise SYSTEMA but there were still some commercial and technical issues which needed to be discussed.

J. Thomas (Alstom) asked whether THERMICA version 4 was already operational within Astrium. M. Jacquiau (Astrium SAS) said that some of the GUI parts were already being used, all of the batch processes were available internally, and there were even a few external users of the batch version. He explained that all of the new features came from the needs of projects within Astrium.

3.5. ESATAN/FHTS and ESARAD: A View on the Near Future

J. Thomas (Alstom) presented details of new and improved areas of functionality within ESARAD, currently being used in-house at Alstom, most of which would be available in the next industrial release. He described how these features would lead to better integration between the tools. (See Appendix S)

H. Peabody (Swales) was interested in the conductor generation facility, and asked whether it would support having two nodes connected to one side. J. Thomas said that he didn’t know the answer off-hand, but would try to provide an answer via e-mail. H. Peabody remarked that there had already been some discussions and issues about conductor generation. HP. de Koning (ESTEC/TOS-MCV) said that the algorithm needed to be independent of the meshing. F. du Laurens (Alstom) said that the algorithm would identify the connect lines but the user could turn some off or add others.

H. Peabody asked whether the STEP-TAS interface was working on Unix, because it was needed for GSS-ATX. HP. de Koning said that the next presentation would address this, so the question could be asked again then if necessary.

3.6. TASverter: Thermal Analysis for Space model converter

S. Appel (ESTEC/TOS-MCV) and HP. de Koning (ESTEC/TOS-MCV) described the TASverter initiative to provide data exchange capabilities in the short term while problems with the development of industrial libraries for integration in the main tools were being addressed. (See Appendix S)

D. Charvet (Astrium SAS) asked whether the converter between ESATAN and SINDA was already available. HP. de Koning said that it was, but only from SINDA85 to ESATAN. It was a two pass converter. The first converted SINDA to its ESATAN equivalent. In the second pass, the converter detected which units were being used, and tried to map to MORTRAN by converting SINDA library routines to the ESATAN equivalent. This conversion was extendible to user routines. The converter was able to resolve most of the MORTRAN but the user still had to do a lot by hand. The data blocks were converted completely.

S. Dolce (ESTEC/TOS-MCT) asked about the verification of the converters: was this a visual inspection, or some intrinsic check? HP. de Koning said that there was a large suite of test cases - currently there were 200 for the TRASYS and 50 for the SYSBAS conversions - and these applied to all shapes and optical properties. For the TASverter itself there was no visual check, and the user needed to see the model in the sending and receiving tools. However, he was confident that the test suites handled all cases. The tool vendors would also have access to the test suites. J. Persson (ESTEC/MSM-MCS) asked how the test cases defined successful conversion. HP. de Koning explained that they had to be some level of inspection although it was possible to use reference definitions to provide some automatic comparison. He admitted that the first time the case was run, the comparison had to be made by hand. The full test suite was available for regression testing against the reference cases.

J. Thomas (Alstom) asked about the source code for the converters: would it be available as open source and could the vendors make changes to it. HP. de Koning said that the converter suite was a prime candidate for release as open source software because it was in the interest of the community as a whole and nobody had a competitive edge which needed to be protected.

E. Werling (CNES) noted the availability of the converter between THERMICA and ESARAD as being the end of the year, and wondered when the other converters would be validated. HP. de Koning said that the test suites were already available, and he was confident in the tools because some large industrial models had also been converted. However, he was interested in users trying their own models. E. Werling asked whether the tools would be available at the start of next year. HP. de Koning said that he wanted to start a full verification campaign involving CNES, Alstom and the other vendors.

3.7. ThermXL v2 and Beyond

J. Thomas (Alstom) demonstrated the latest features of ThermXL using a prepared example, and described future developments. (See Appendix S)

J. Persson (ESTEC/MSM-MCS) commented that he hadn't seen whether ThermXL supported time-profile data, like those handled in the ESATAN $ARRAYS block. J. Thomas said that ThermXL was built on top of Excel, so it was possible to use any Excel function within the spreadsheet and to apply a function to a particular cell. He demonstrated on screen that the user could define any data cell to be dependent on a set of other data cells, such as those containing time dependent data. The user could then write a Visual Basic macro to interpolate the data within these cells as needed. He explained that there was an example in the ThermXL tutorial which demonstrated this. Version 3 of ThermXL would get rid of the need for some of this by providing a specific INTERP function. O. Pin (ESTEC/TOS-MCV) added that ThermXL provided equivalent mechanisms to the $VARIABLES2 block in ESATAN. He said that if time varying variables had not been available then ThermXL would have been useless. HP. de Koning (ESTEC/TOS-MCV) remarked that because the whole spreadsheet was recalculated at every time step it was possible to refer to individual variables during the time marching.

E. Werling (CNES) wanted to know about the relative speed of ThermXL compared to ESATAN. J. Thomas explained that ThermXL had never been intended as a replacement for ESATAN as it could only handle small models. There was an Excel limit of 255 columns in the spreadsheet, and this meant that ThermXL could handle a maximum of 254 nodes. He admitted that the more complexity the user added into the spreadsheet, the more work Excel had to do to recalculate it every time, so the calculation became slower. However, he stressed that the tool had never been aimed at handling large models.

4. Wednesday 23rd October: Afternoon Session

4.1. ALTAN application for Bepi-Colombo thermal analyses

V. Perotto (Alenia) described aspects of the Bepi-Colombo mission which could not be modelled using the existing tools - namely directional reflectivity, the finite size of the sun, and non-uniform planet temperature -and the software which had been developed to handle these problems. (See Appendix S)

There were no questions.

4.2. Last Developments in and around GAETAN

C. Marechal (CNES) described the changes to the GAETAN software which had been made since it had been presented at a previous Workshop, and also gave some details of CONDOR, an internal CNES tool to help find dimensioning cases for given orbit parameters. (See Appendix S)

S. Dolce (ESTEC/TOS-MCT) asked for a more detailed explanation of the semi-automatic model reduction available in GAETAN. C. Marechal said that he had already given a presentation on the model reduction feature at the Workshop three or four years ago. E. Werling (CNES) explained that it was a physical method, and that all thermal flux analysis and heater data could be taken into account. He stressed that this involved an energetic and physical approach and was not based on stochastic methods. S. Dolce asked whether the reduced model was a physical representation of the original model. E. Werling gave the example of the INTEGRAL spectrometer which had yielded a factor of 100 model reduction. He confirmed that the physical meaning of the model was retained. He explained that this was why the algorithm was only semi-automatic, in order to keep the physical meaning and to allow the user to define the appropriate node groups.

4.3. NASA Space Environment Specification

HP. de Koning (ESTEC/TOS-MCV) gave a brief news bulletin that a new Space Environment Specification was available from NASA and that it might form a useful foundation from which many projects would be able to draw common definitions.

The complete reference for the document is:[6]

> NASA/TM-211221, Anderson, B.J. and Justus*, C.G. and Batts*, G.W., Guidelines for the Selection of Near-Earth Thermal Environment Parameters for Spacecraft Design, George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812, National Aeronautics and Space Administration Washington, DC 20546-0001, Prepared by Engineering Systems Department, Engineering Directorate *Computer Sciences Corporation, October 2001, pp. 32, Format(s): PDF 1885k.

4.4. CAD-FE integration using Open Source Software

C. Caillet (OpenCASCADE) described the design requirements for an open source framework for building numerical simulation tools, and how the SALOME system had been developed and was currently being used. (See Appendix S)

HP. de Koning (ESTEC/TOS-MCV) said that the OpenCASCADE framework was already available as open source software. He asked whether SALOME would also be available. C. Caillet said that SALOME had not yet been industrialised: it was still being built and tested.

4.5. Final Discussion and Conclusions

L. Maresi (ESTEC/IMT-THH) had put together a series of viewgraphs based on the earlier session on Harmonization and the Round Table discussion. These needed further discussion to ensure consensus. (See Appendix Y)

C. Stroom (ESTEC/TOS-MCV) started the discussion with point 1 (general consensus was expressed on the role of ESA for defining standards for data exchange). He explained that the work on data exchange had been a major priority and would remain so in the near future. Data exchange needed to be based on open standards. Standards needed to be of high quality, stable and should never be based on a proprietary definition. The latter point was important to ensure that the standards did not fall under the control of one company. STEP was therefore the best solution.

S. Dolce (ESTEC/TOS-MCT) said that standards should be made available quickly. In Europe, there was a constant need to exchange thermal models between different tools. Developing a perfect standard and solution for this problem might still take a significant amount of time. It was important to focus on quality but flexibility and short-term availability should also be taken into account.

C. Stroom explained that developing standards was never fast. He said that the earlier presentation by H. Peabody (Swales) had been a good indicator of the number of issues that had to be solved up front before it was possible to define workable standards. It was indeed a meticulous task. The same remarks could be expressed for the ECSS standards. In many cases

6. The URL to this document which was shown at the Workshop is no longer valid. The document is currently available at http://trs.nis.nasa.gov/archive/00000581/

an initial plan involved 2 years to establish a standard, but in reality it taken far longer. C. Stroom said that he understood the frustration of the users who wanted to have a solution for data exchange in a short-term. On the other hand addressing only the short-term could lead to the non-availability of a long-term and more efficient solution.

S. Dolce said that TASverter was a good initiative because it would provide a solution for exchanging thermal models in the short-term. HP. de Koning (ESTEC/TOS-MCV) explained that ESA recognised the need for a short-term solution and this was exactly why the development of TASverter had been initiated. He admitted that from the users' point of view no significant progress had been made since the establishment of the STEP-TAS protocol in December 1996, 6 years previously. He was the first one to be disappointed by the lack of progress given his direct involvement during this time, both in industry and now at ESA. He pointed out that software vendors generally considered the need to interface their tools with standards as a second priority. There was also the fact that the technology chosen at that time had been quite complicated, with an approach that had been more academic than industrial. Now that lessons had been learnt he was confident that a more industrial type of environment could be used for the development of STEP-TAS and STEP-NRF.

C. Stroom had two additional remarks. Apart from the fact of using more efficient software technology it was clear that all efforts of the past had not been wasted. For example TASverter was based on the STEP-TAS protocol definition. He also explained that the project had suffered from two and a half years of delay because of the very poor performance of the main Contractor. The activity had lacked focus and in many times promised deliveries had not been made. He felt that this was one of the good reasons to go to an OSS distribution model to ensure that the overall development would not be jeopardised by the poor performance of a single company.

C. Caillet (OpenCASCADE) agreed with HP. de Koning on the fact that STEP had been a bit of a "University type" development. It was important to focus on a relevant subset for users. For example, CAD was not fully covered in Salomé but a reasonable subset was available. It was also important that the users themselves were involved by providing test cases to software vendors and by making sure that their needs were considered. Users needed to push and not wait for the standards to be available.

H. Peabody (Swales) said that as a user he did not care too much about how to go from tool A to tool B. To answer a previous comment made by C. Stroom he said that TSS was not a proprietary format but an ASCII fixed format. He remarked that in any case there would be a need to update STEP-TAS/NRF when new functionality was needed, for example for sub-modelling. HP. de Koning replied that sub-modelling was already supported in the STEP-TAS/NRF data models. The current problem had not been in the standards themselves but in their implementation.

P. van Leijenhorst (Dutch Space) said that, in his opinion, priority should be given to the development of a solution for data exchange. He was in favour of option 1, data exchange and nothing more. The tool kit was not a priority. HP. de Koning agreed that there was a general consensus for having data exchange as a first priority. However, providing a solution for data exchange was not contradictory with the development of a tool kit. ESA should produce a stable and effective data exchange component but the tool kit could be addressed as a further step.

C. Stroom asked P. van Leijenhorst about his expectations for the next 5 years and was told that he wanted a working solution for data exchange. He had no further expectations. C. Stroom explained that ESA considered data exchange as a matter of first priority and that parallel activities such as TASverter would also be carried out internally at ESA to ensure that a backup would be available. He didn't believe, however, that just adding six extra people to the team would necessarily produce quicker initial results. He had been able to allocate one and a half engineers with relevant expertise to work on data exchange at ESA, and he felt that activities were back on track and ESA would deliver as promised.

HP. de Koning (ESTEC/TOS-MCV) said that users had to realise that work would need to start a long time in advance if a tool kit was wanted. It would probably take one year or more for the preparatory work. It was therefore necessary to address data exchange and the tool kit in parallel - and starting now - but still focusing on the immediate need to deliver working protocols for data exchange.

C. Stroom said that one of ESA's goals was to develop long-term solutions for thermal analysis tools and that we were at the beginning of a necessary review with users. He was therefore interested to hear what the users in the room would ask for once the data exchange protocols had been made available. P. van Leijenhorst said that all he wanted was not to have the same discussion on data exchange next year.

H. Peabody said that users had to realise that it was not possible to produce something perfect from the start. It was up to the users to assess whether a converter was right. The only way to have working solutions for data exchange was to have full involvement of the users. He was therefore of the opinion that STEP-TAS/NRF and associated converters should be released now and users could then detect any possible problems with the protocol and converters and help in their consolidation. HP. de Koning and C. Stroom agreed.

C. Stroom proposed to move to point 2 (the age of the current software tools and the increasing maintenance costs were major drivers for new development).

P. van Leijenhorst disagreed with the statement. The existing software tools were adequately doing what they were supposed to do. S. Dolce thought the contrary, and that there was a need for improvement.

C. Stroom gave the example of the requirements for Bepi-Colombo to explain that the development cost of existing tools could inhibit the availability of new critical functionality.

V. Perotto (Alenia) said that all requirements for thermal analysis tools originated from missions requirements in one way or another. If new functionality was requested for a mission then this should be implemented in the set of thermal analysis tools.

HP. de Koning said that a related issue was the need to support scientific missions which had very strong requirements for detailed analysis and verification. These scientific missions brought up a new class of required functionality. The age of the existing tools resulted in increased implementation costs, and this had an adverse impact on the availability of this new functionality. Another good example of new issues to be addressed related to the new generation of high power satellites. The analysis tools had to be scalable, for example, in order to support 20000 node models and benefit from modern high-performance computing.

C. Stroom said that he would modify the formulation of point 2. He then moved the discussion to point 3 (Tool kit would be funded through ESA TRP/GSTP) which was more a statement than a point for discussion and to point 4 (user shall be involved). Everyone agreed that the involvement of the users was necessary. Points 5, 6 and 7 were then re-stated. C. Stroom said that the presentation about OpenCASCADE / Salomé had shown the feasibility of the open source approach outlined in point 7 (some users prefer turn-key solution. Is this possible with an OSS approach? -Yes). There were no further comments on points 5, 6 and 7.

C. Stroom presented point 8 (the effort required to move the users from the tools used daily to a new environment seems to be the major barrier to overcome). He insisted on the fact that tools were part of the work flow and modelling environments and there was therefore a natural tendency for the users to avoid modifying the tools and hence work flow and environment unless this was not an absolute necessity. However, retaining backwards compatibility of tools was also a major obstacle to their evolution and this had to be considered.

S. Dolce asked more specifically what were the conclusions of point 8. Was there any way to change this? HP. de Koning said that any new development would need to be accompanied by a migration path for existing tools. C. Stroom explained that running projects needed to be supported and it was clear that they would not change tools.

S. Dolce said that this was related to earlier discussions that had taken place during the Workshop. There had been 2 or 3 versions of ESARAD recently but it was necessary to guarantee access to the same version during the course of a project. A project could not always afford the CCNs and RIDs which would be issued by industry as a result of a change in the version of ESARAD specified in the original contracts.

C. Stroom said that no commercial tool vendors would support more than two or three versions. If problems were found it was not possible to implement corrections in older versions as this would be prohibitive in cost. This was one of the additional advantages of the OSS approach because it was possible to re-compile a tool for own use.

C. Caillet (OpenCASCADE) said that you should change tools only when starting a new project and not during the course of the project. E. Werling (CNES) commented that typical space projects lasted for 8 to 10 years. C. Caillet said that in the typical life cycle in the automotive industry was in the order of 4 to 5 years.The aeronautical industry also encountered long life cycles and there was the need to address tool and model migration. This came back to the already-discussed need for efficient data exchange. It was also necessary to retrieve data for later use. For instance, computations still had to be carried out for Concorde more than 30 years after the original development.

C. Stroom said that, related to the last point, he had been surprised that archiving data had not been identified as an important aspect during the user survey. S. Dolce said that the long life cycle of space projects was a fact of life and that there was therefore the need to keep backwards compatibility and to support more than one version. C. Stroom repeated that this would prove far too costly in practice. He expected that the software cost would triple. H. Peabody agreed and said that for ThermPlot he was concentrating on interfacing with the most recent version revision of the other tools.

S. Dolce said that he did not want to re-experience what had happened during the METOP project. Moving from ESARAD 3.2.7 to version 4.2 had been a significant issue for both industry and ESA. C. Stroom said that he fully understood the issue but that with the current resources it would simply be impossible to support more than one version of the tools. H. Peabody suggested to S. Dolce that maybe the best approach was simply to wait before upgrading.

J. Thomas (Alstom) explained that in practice users usually had more than 1 year to carry out a migration. He also pointed out that this was sometimes a significant constraint for Alstom. For instance ESARAD 3.2.7 used ORACLE but there was no longer any ORACLE expertise within the development team.

E. Werling said that it was currently possible to use the current and the previous versions and that in his opinion this was satisfactory. Only in some particular cases was it necessary to work with older versions.

C. Stroom moved to points 9, 10 and 11. There were no comments.

E. Werling wanted to return to point 1. He said that CNES had agreed, in principle, to support STEP-TAS, STEP-NRF, STEP-SPE and STEP-AP/203. However 6 years had passed without having a reliable STEP-TAS. He felt that something needed to be done from the management point of view and that lessons should be drawn to ensure that the situation would be corrected in the future. In particular, the validation of these protocols required a complex industrial organisation with vendors, industry and agencies and it was necessary to define this in detail. Concerning point 2, he agreed with the statement made. Concerning point 3, he said that something was required to replace ESABASE but he had some doubts about the need to develop a tool kit for thermal control analysis. This was obviously linked to point 8 (migration from existing tools). Moving users from ESABASE would not be a problem. However moving the thermal control engineers from their existing tools would be more difficult because of the development environments which had been put in place around these tools. He was of the opinion that it would be more sensible to build around the existing tools, with the idea of capitalising on more than 20 years of know-how and past effort, rather than re-build everything from scratch.

C. Stroom said that his position on this matter was related to point 5. To be competitive this had to be considered and this could conflict with what E. Werling had just said.

E. Werling then moved to point 4. He said CNES agreed with having a web site in place but this was not sufficient. What was necessary was to have thorough discussions with users during working meetings. He thought that users should also be involved when defining the strategy of thermal analysis tools. H. Peabody agreed that the user should always drive the process of tool development. Software vendors were always more efficient when replying to user’s requests. J. Thomas also agreed.

E. Werling asked whether something more practical could be put in place for the current Thermal and ECLS Software Workshop. Or whether it might be useful to hold an additional workshop in Toulouse consisting of a 2 day meeting involving 40 or 50 invited participants. Some round-table discussions could be set-up to capture high-level user requirements with the objective of formalising them. C. Stroom said that any suggestions were welcomed.

E. Werling insisted that there was a real problem of communication between software developers and users.

J. Thomas, taking the example of Bepi-Colombo, said that they were about to start upgrading ESARAD. But unfortunately they had not been made aware until very recently of the user's needs.

M. Jacquiau (Astrium SAS) had some comments on point 5. He wanted to explain the philosophy followed for THERMICA and SYSTEMA. A lot of components of THERMICA were common components of SYSTEMA. In practice, this meant that developments for THERMICA could be shared with others, as part of the SYSTEMA framework. HP. de Koning commented that Astrium was a special case because it was one company for which sharing was possible given the overall volume of their activities.

C. Stroom wanted to come back to the issue of the requirements for Bepi-Colombo that had not been correctly addressed. He admitted that there had been a period during which the quality of the tools was lower. V. Perotto asked C. Stroom why the information had not been provided to his section. C. Stroom explained that in some cases the information was available but in other cases it was not. He also reflected on the fact that it was generally difficult to convince the projects to support developments if there were no benefits to the project in the short-term.

HP. de Koning said that what had happened for Bepi-Colombo was a very good illustration of potential problems that could occur when a company played a double role. Astrium were competing for the mission and were also software vendors. Solutions needed to be found to overcome such potential conflicts of interest.

4.6. Workshop Close

C. Stroom (ESTEC/TOS-MCV) thanked everyone for their participation, and closed the Workshop.

Appendix A: Welcome and Introduction

Welcome and Introduction

C. Stroom
ESTEC/TOS-MCV

esa

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Thermal and Structures Division

Workshop objectives

- To promote the exchange of views and experiences amongst the users of the Agency's (and others) software packages in the fields of thermal control and ECLS
- To provide a forum for contact between end users and software developers
  - Free and open discussions.
- To present new versions of the software tools and to solicit feedback for development

ESTEC
Thermal and Structures Division

ESA team

Charles Stroom	Head of the Analysis & Verification Section
Duncan Gibson	Software Support & Workshop Secretary
Hans Peter de Koning	ESARAD, Polytan & Model Data Exchange
Olivier Pin	ESATAN, FHTS, ThermXL & EcosimPro

Simon Appel, David Alsina i Orra, Ricardo Patrício Dias, Luis Ordonez Inda

ALSTOM team

Julian Thomas	Project Leader
Frédéric du Laurens	Support Manager

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Programme

- Two-day Programme
- Presentations include 5 minutes for questions and discussions.
- today - ESA Round-Table discussion following the ESA Harmonisation paper (Hans Peter de Koning).
- Cocktails today after round-table discussion
- Dinner (option) tonight in Noordwijk
- Conclusions tomorrow at end of Workshop

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Thermal and Structures Division

Tuesday 22 October Morning

09:00 Registration

10:00 Welcome and Introduction

10:05 Arend Woering, et al., NLR, Two-phase thermal control for the AMS-02 Silicon Tracker

--:-- Shengping Luo, CNRS, 3D numerical simulation of turbulent heat and mass transfer processes in an ECLS system **(will not be presented!)**

10:25 Rachida Ameziane, EADS – Launch Vehicles, Simulation for Analysis and Validation of Energy (SAVE) management platform for ATV

10:45 Olivier Pin, ESA, On-going Work, incl. Stochastic, Thermo-hydraulic solvers and others.

11:15 Coffee break

11:20 Nick Cavan, RAL, Modelling the VISTA Infrared Camera

11:40 Jayne Fereday, RAL, Thermal Analysis of Planck HFI

12:00 Frédéric du Laurens d'Oiselay, et al., ALSTOM, ESARAD v5

12:20 Alexander Rodriguez, et al., ESA, Application of EcosimPro to Bio-regenerative Life Support Components

12:40 Frédéric du Laurens, et al., ALSTOM, ESATAN/FHTS v8.7 & v8.8

13:00 Lunch

ESTEC
Thermal and Structures Division

Tuesday 22 October Afternoon

14:00 Johannes van Es, et al., NLR, Integrated thermal design and the thermal numerical toolbox

14:20 Marc Jacquiau, Astrium F, Thermal simulation in functional analysis

14:40 Reinhard Schlitt, et al., OHB, Development of Algorithm to Interface LHP S/W Model with ESATAN Thermal Mathematical Model

15:00 Elizabeth Seward, Astrium UK, Use of ESARAD in MetOp Thermal Testing Analysis

15:20 Coffee break

15:35 Hans Peter de Koning, ESA, ESA Harmonisation & User Survey

16:05 Round Table Discussion

17:30 Social Gathering

20:00 Dinner (tbc)

Wednesday 23 October Morning

09:00 Hume Peabody, Swales Aerospace, Use of TSS as a neutral format for geometry model conversions: an alternative to STEP-TAS

09:30 Jean-Paul Dudon, et al., Alcatel, CIGAL2: A new open source pre-post processing tool for Coratherm

10:00 Christian Ruel, MAYA, TMG: New Technologies and Modelling Approaches

10:30 Marc Jacquiau, Astrium-F, Systema/Thermica version 4: overview of the new capabilities

11:00 Coffee break

11:30 Julian Thomas, et al., ALSTOM, ESATAN/FHTS & ESARAD: A View on the Near Future

12:00 Simon Appel, ESA, Tasverter, a converter between ESARAD and Thermica

12:30 Julian Thomas, ALSTOM, ThermXL v2 and beyond

13:00 Lunch

Wednesday 23 October Afternoon

14:00 Valter Perotto, Alenia Spazio, ALTAN application to Bepi-Colombo thermal analyses

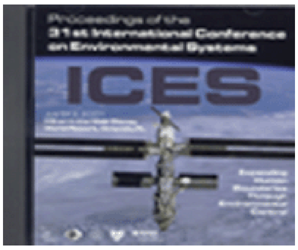
14:30 Christophe Marechal, CNES, Last developments in and around GAETAN

15:00 Coffee break

15:15 Vincent Ruelland, Open CASCADE, Salome, an open source platform dedicated to CAD/FE integration for numerical simulation

15:45 Final discussion and conclusions

16:15 End of Workshop



ICES 2003

- The 33rd International Conference on Environmental Systems will be held 7-10 July, 2003, Vancouver, B.C., Canada
- Deadline for submitting abstracts: 8 November, 2002
- Thermal software related abstracts to be sent to: Olivier Pin, email olivier.pin@esa.int

Practical Information

- Presenters: please leave your presentation (floppy or CD-ROM with PowerPoint file) with Duncan Gibson or Charles Stroom before the end of Workshop. Please leave a paper copy if possible to avoid problems with embedded fonts/logo’s or Mac.
- No copyrights, please!
- Workshop Minutes will be supplied to participants, in hard copy and on the Web.

Practical Information

- Lunch: 13:00 - 14:00. The “Foyer” tables are reserved for us
- Cocktail today at 17:30 in the Foyer (near the canteen)
- Fax (+31-71-565-5949) and telephone available outside the Workshop room
- Check your details on the list of participants and inform the Conference Bureau of any modifications. Check your email address!

Dinner (tbc)

- "Dutch" dinner == you pay for yourself:-(
- in "de gulle Tjon", Huis ter Duinstraat 27, Noordwijk a/Z
- 3-course fixed menu with options for 33.50 euro, excl drinks
- Restaurant booked today for 20:00 (maps available). Please arrange your own transport
- If you would like to join, and you have not yet sent a confirmation email which I have seen, complete a form; sheets are available
- ultimate time today: 14:00, to let the restaurant know.
- Check your entry!

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Naam	Entree				Main course		
	Carpaccio	Ragout	pheasant soup	fish soup	codfish	lamb	pheasant
Charles Stroom		1				1	
Elizabeth Seward			1			1	
Marc Jacquiau				1			1
Andy Robson		1				1	
Rachida Ameziane				1	1		
Julian Thomas				1			1
Frédéric du Laurens	1						1
Christian Ruel			1		1		
Hans Peter de Koning	1					1	
Nick Cavan				1			1
Hume Peabody			1			1	
Olivier Pin		1					1
Eric Werling				1			1
Vincent Ruelland	1					1	
Jayne Fereday			1			1	
Maurizio Rossi				1		1	
Totaal	**3**	**3**	**4**	**6**	**2**	**8**	**6**

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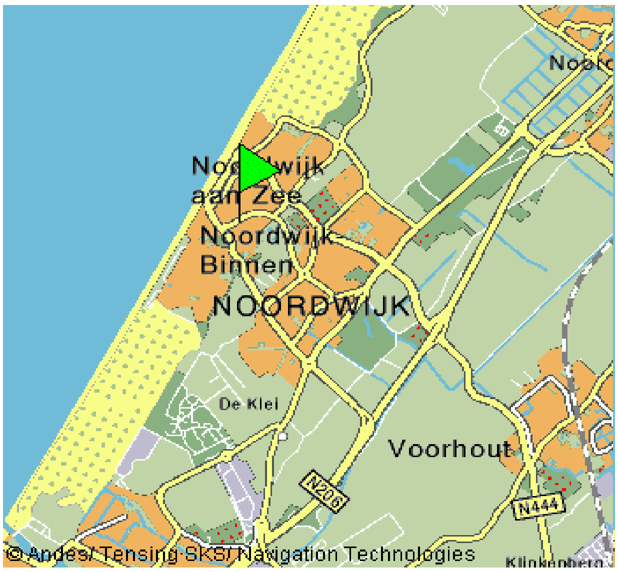
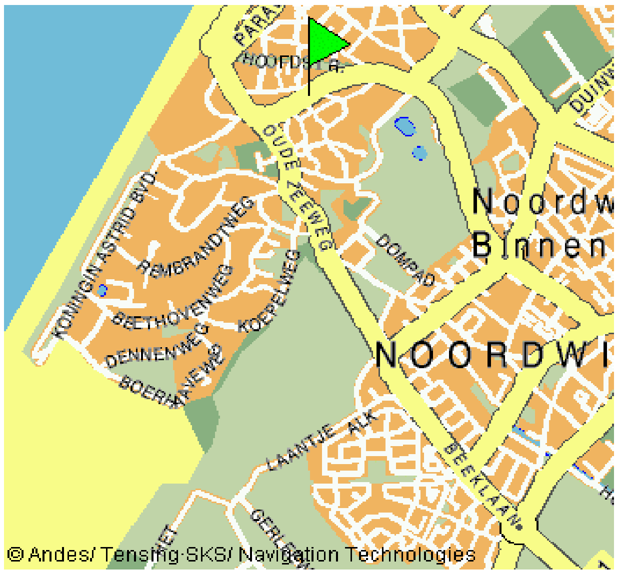
Resto "de gulle Tjon"





Appendix B: Thermal Modelling Issues Concerning the Mechanically Pumped Two-Phase CO_2 Cooling for the AMS-02 Silicon Tracker

Thermal Modelling Issues
Concerning the
Mechanically Pumped Two-Phase CO_2 Cooling
for the
AMS-02 Silicon Tracker

A. Woering
NLR

Thermal Modeling Issues Concerning the Mechanically Pumped Two-Phase CO_2 Cooling for the AMS-2 Tracker

A.A.Woering, A.Pauw, A.W.G. de Vries, A.A.M. Delil

National Aerospace Laboratory NLR, The Netherlands

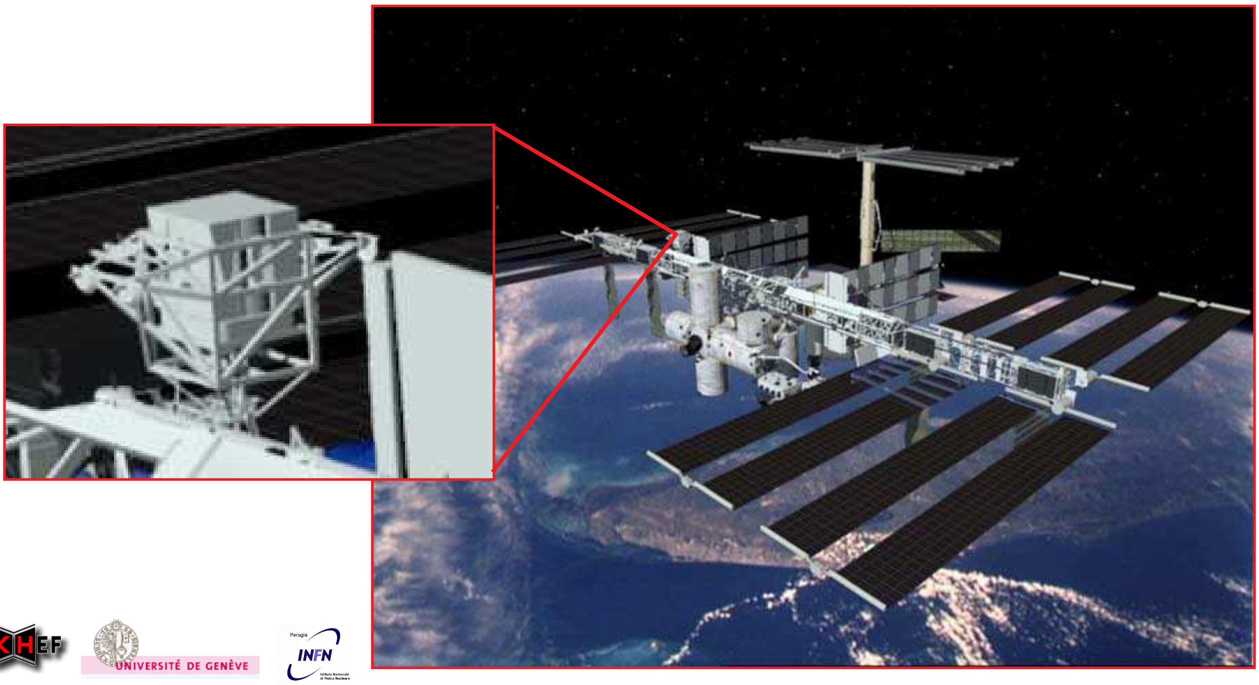
B. Verlaat

National Institute for Nuclear and High-Energy Physics NIKHEF, The Netherlands

Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

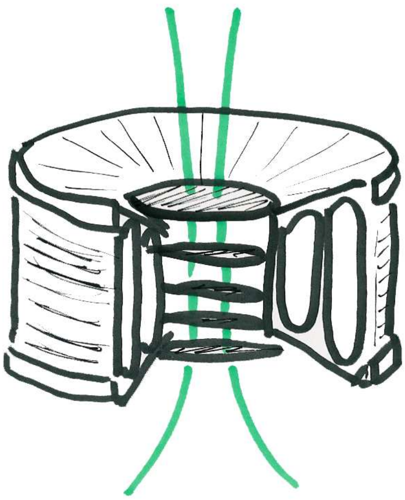
Contents

Alpha Magnetic Spectrometer



Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

AMS Silicon Tracker



- **(x,y,z) particle trajectories determined by momentum and charge sign**
  - Curvature radius : momentum
  - Curvature direction : charge sign
- **Energy loss in each silicon plane yields charge magnitude**

NIKHEF UNIVERSITÉ DE GENÈVE INFN

AMS Silicon tracker thermal requirements

Silicon wafer thermal requirements:

- ***Operating temperature:***
  -10 ºC / +25 ºC
- ***Survival temperature:***
  -20 ºC / +40 ºC
- ***Temperature stability:***
  3 ºC per orbit
- ***Maximum accepted gradient between any silicon:***
  10.0 ºC
- ***Dissipated heat:***
  2.0 Watt EOL

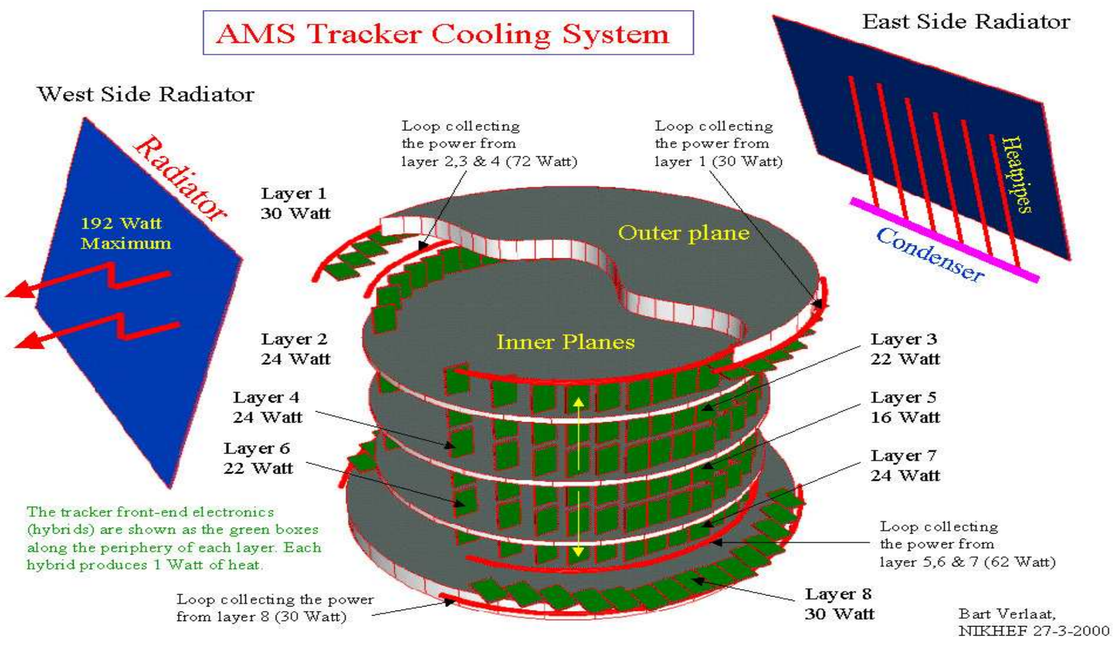
Hybrid circuit thermal requirements:

- ***Operating temperature:***
  -10 ºC / +40 ºC
- ***Survival temperature:***
  -20 ºC / +60 ºC
- ***Dissipated heat:***
  192 Watt total, 1 Watt per hybrid pair

General requirements

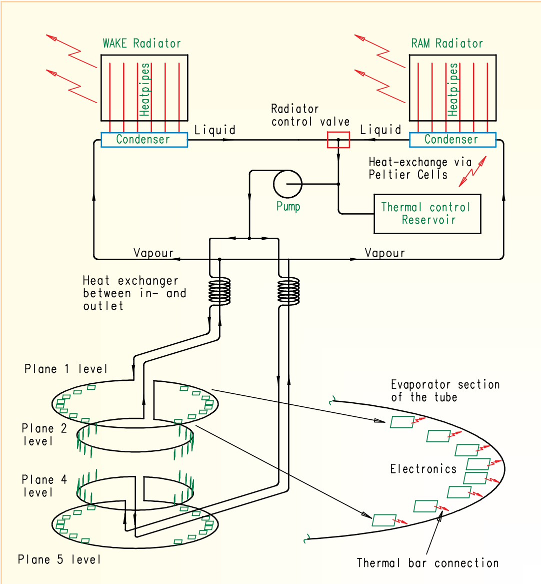
Limited mass (70 - 80 kgs)

Limited power (< 80 W)

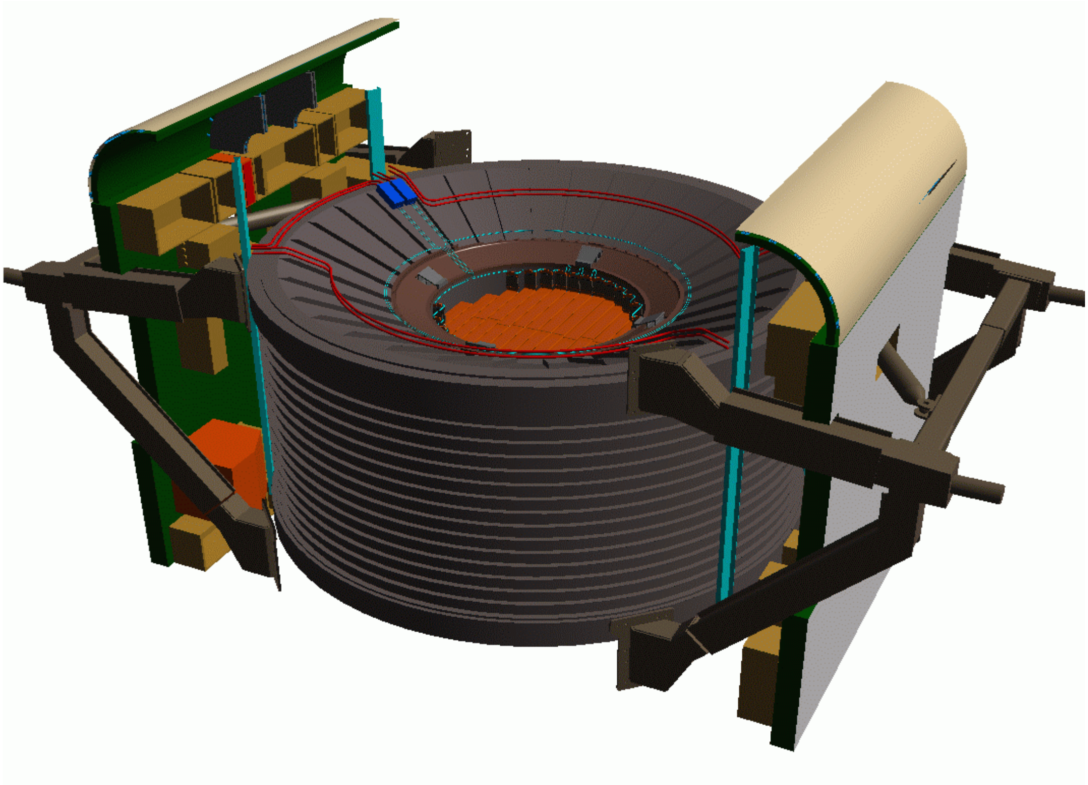


Heat dissipation in the AMS-Tracker

TTCS summary

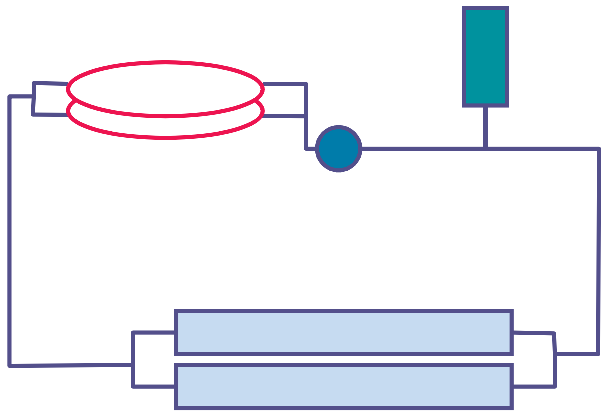


- 2 Identical completely separated loops (1 for redundancy)
- 2 serial evaporators in parallel per loop
- 2 parallel condensers controlled per loop controlled by a 3-way valve.
- Pressure controlled with a thermal control reservoir
- Thermal control using standard AMS control module
- Critical components in redundant configuration (pump, valves)
- Most fluid components in 2 dedicated TTCS boxes on the support structure at wake side
- RAM and WAKE heat pipe radiator
- All hardware is placed in debris-safe areas; a specific debris shield is added when needed

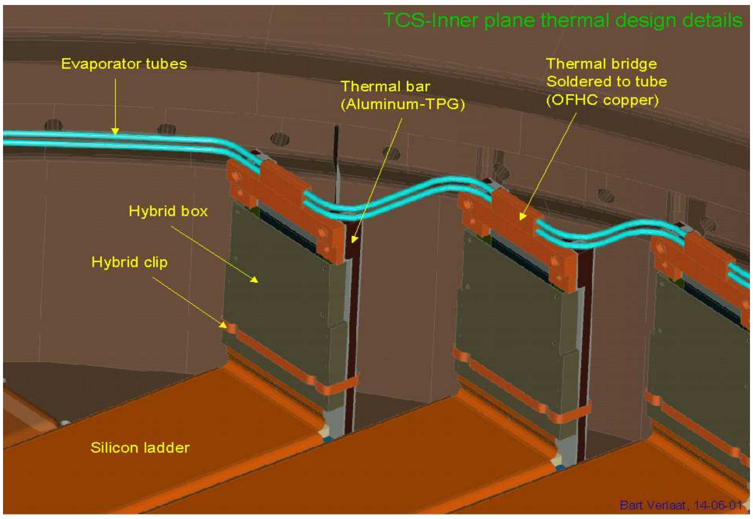


Tracker (component) design

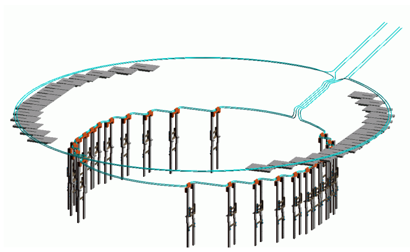
- 2 parallel evaporator branches
- 2 parallel condenser branches, 2 radiators
- pump assembly



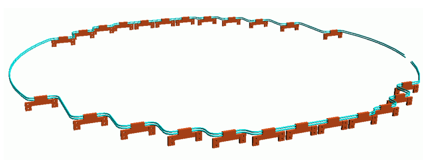
Evaporator



TTCS evaporator connection to inner thermal bars



Complete thermal system in side the tracker (Thermal bars+ evaporators)



Inner planes evaporator

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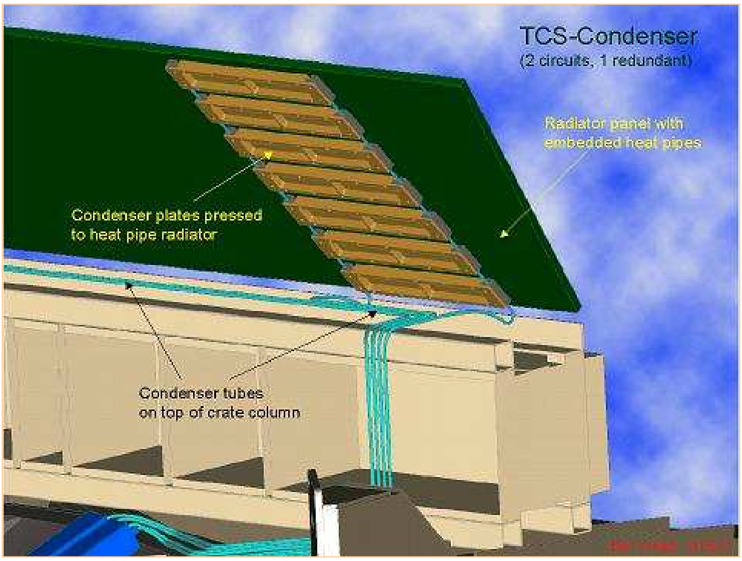
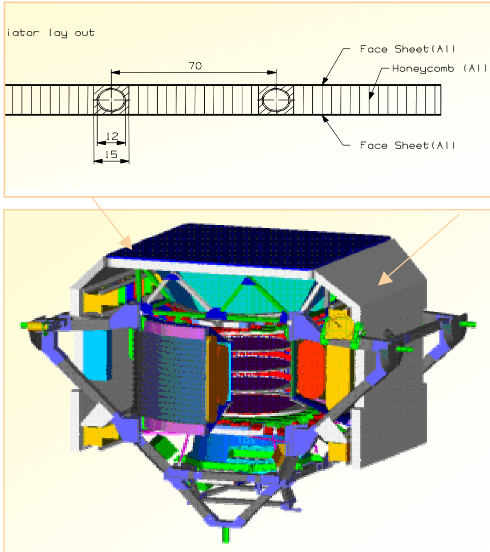
Radiators





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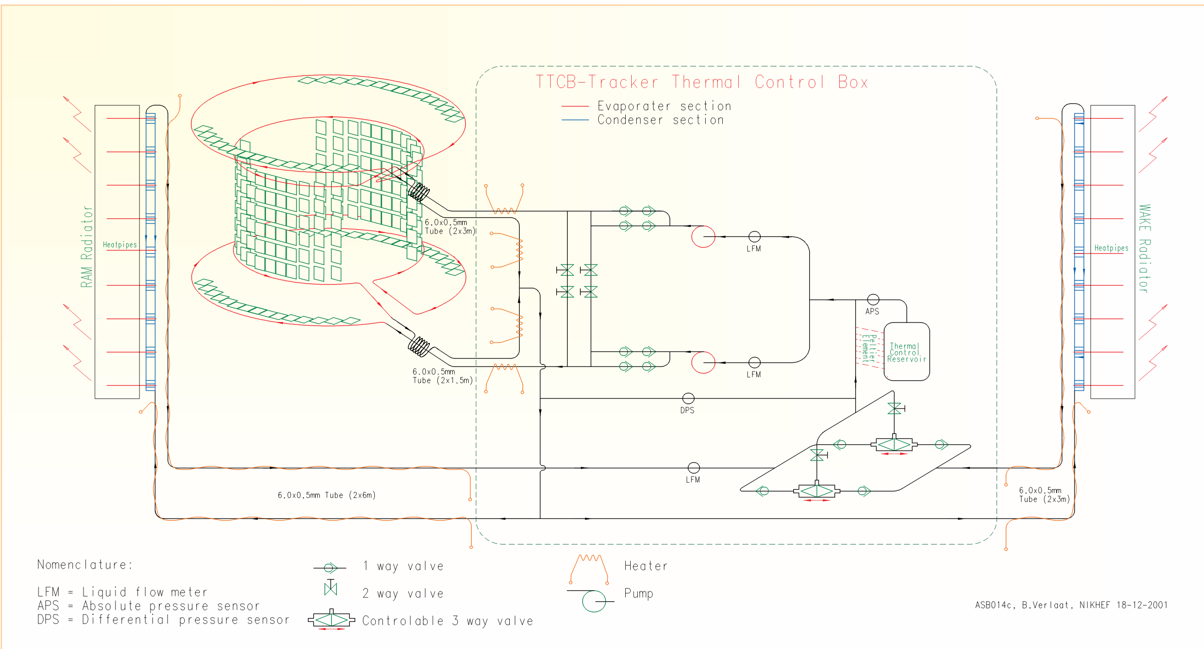
Plumbing schematic



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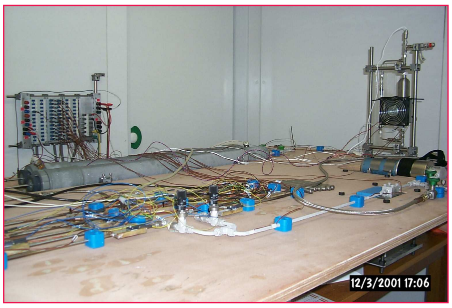
Experiments

- **Feasibility test set-up @ NIKHEF**
- **Control BBM @ NLR**
- **Real size BBM @ NLR operational since early this year**
  - First tests are promising
  - Full test campaign expected to start in fall 200



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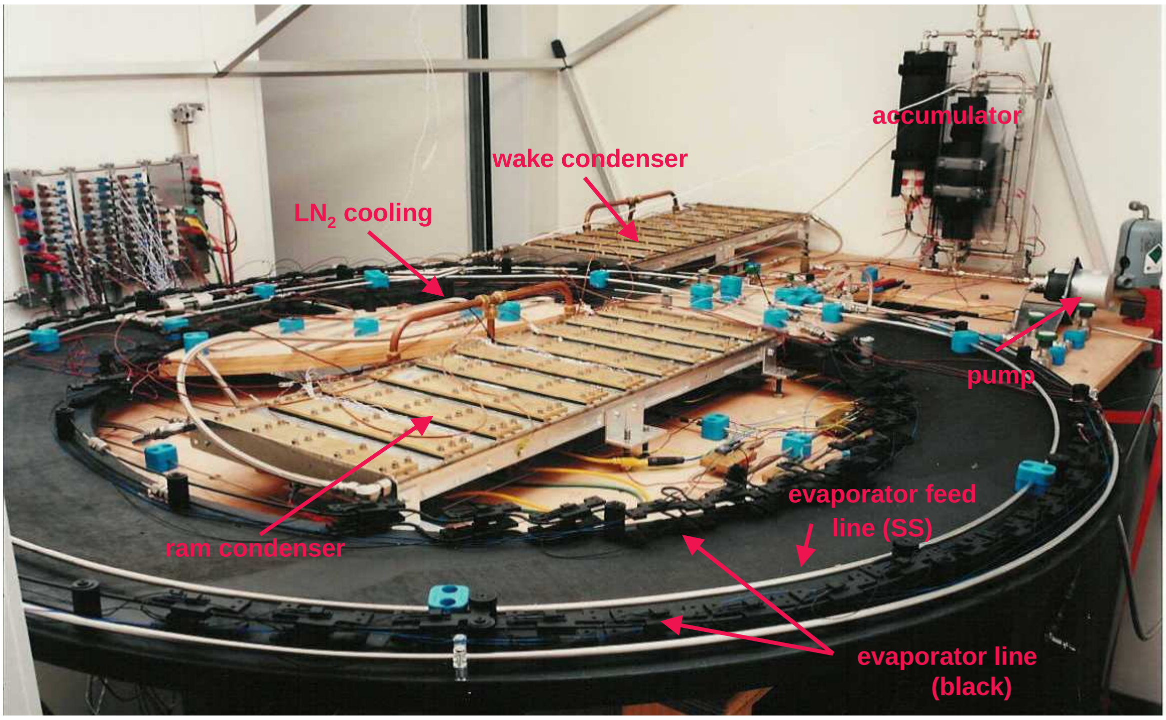
Breadboard



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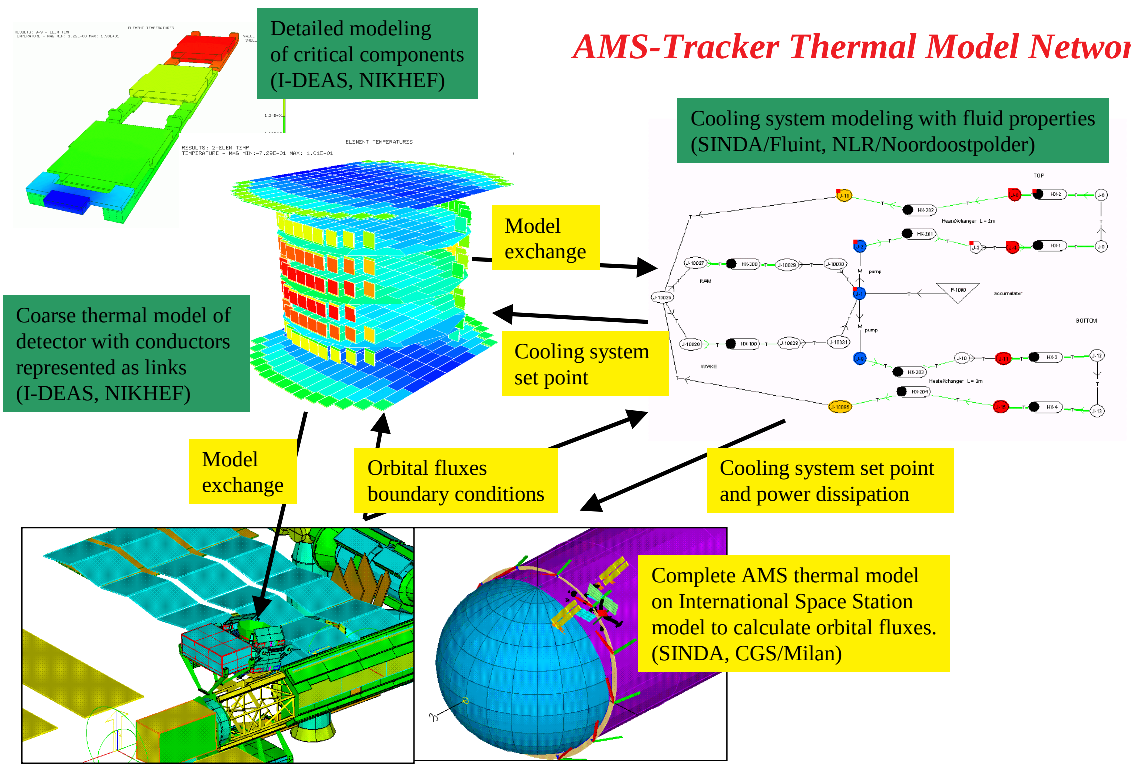
Numerical modeling

- **Modeling information flows**
- **Component modeling fixed with loop temperature**
- **Simulation cases for design optimization**
  - Radiator size, mass and shape
  - Heat pipe puncture
  - Preheating

AMS-Tracker Thermal Model Network



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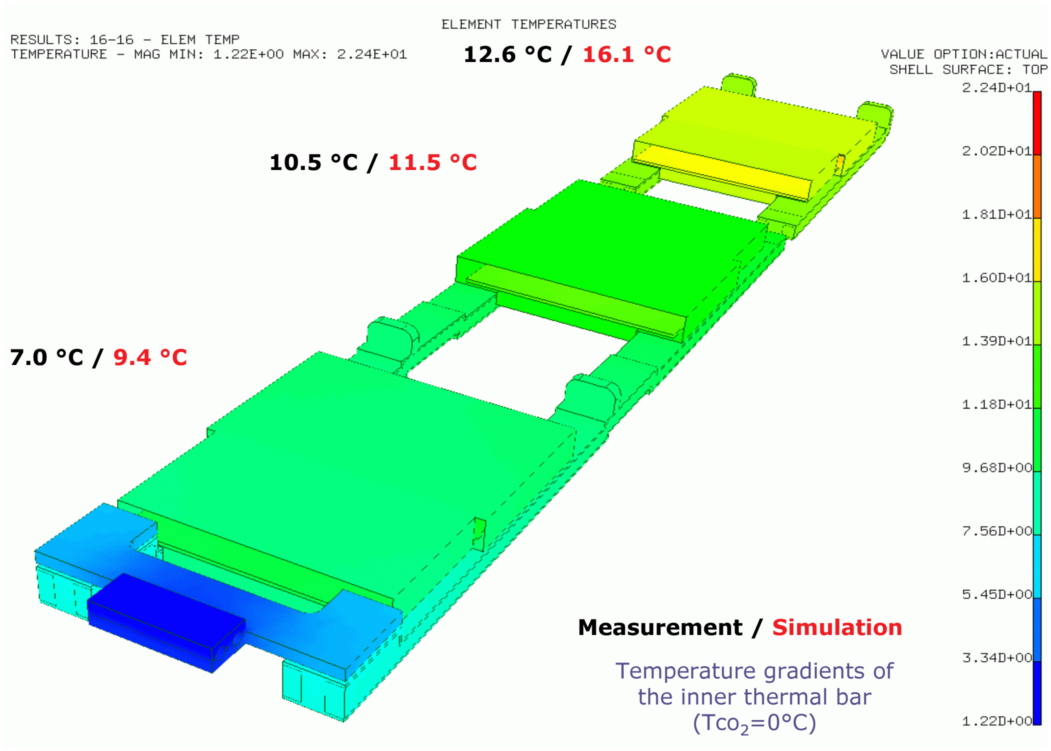

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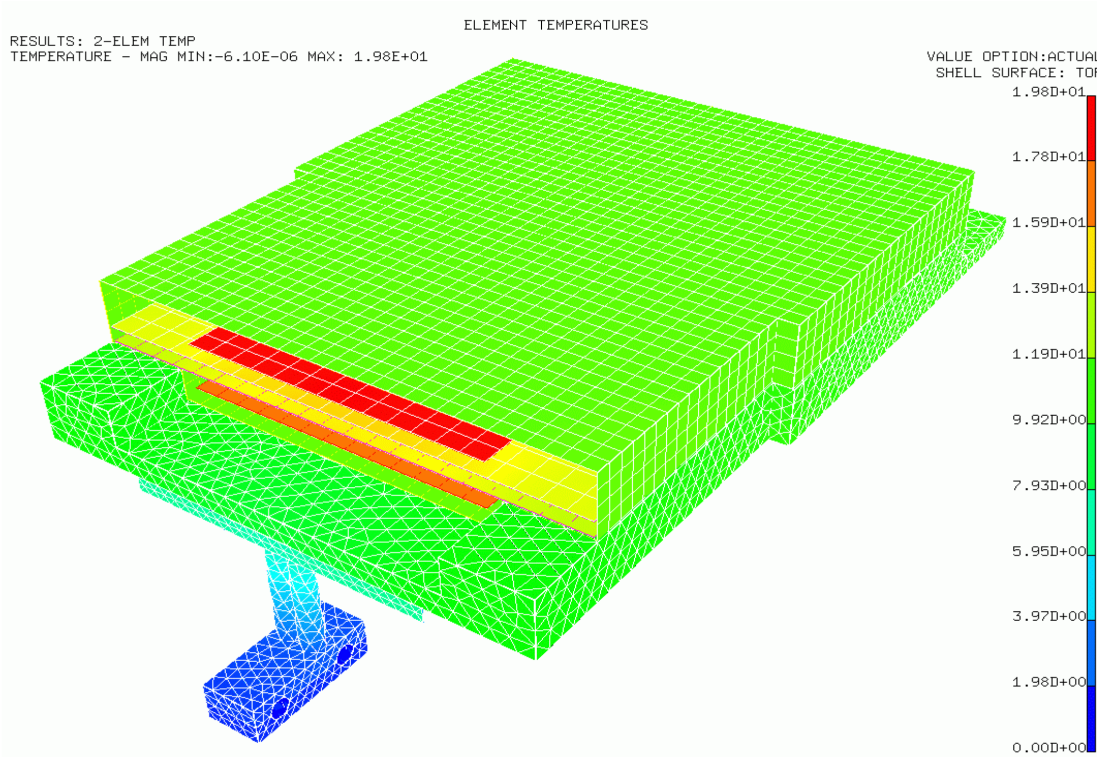

uter plane thermal bar thermal simulation

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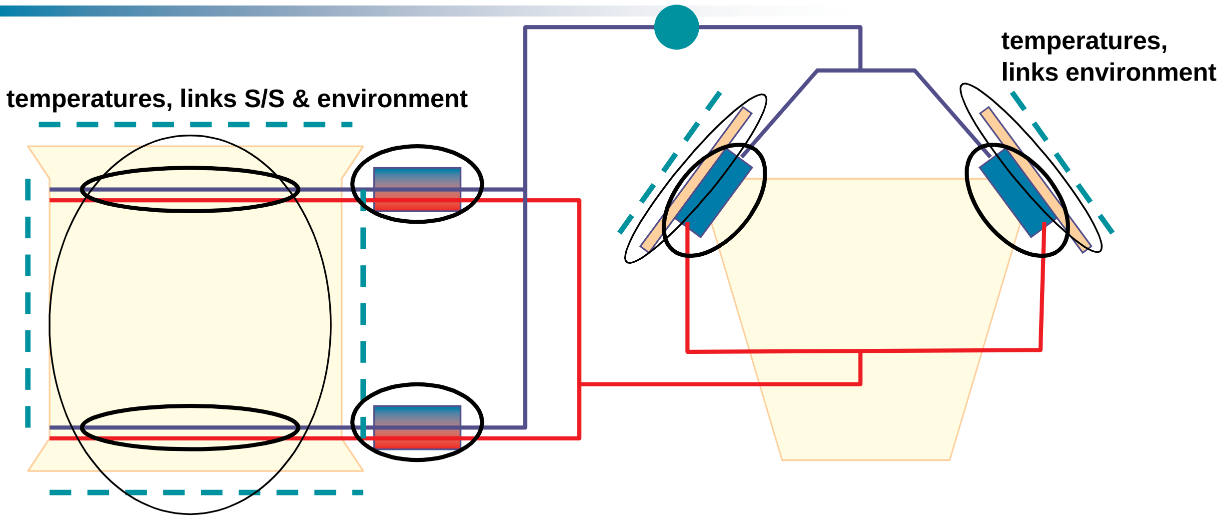
Loop model



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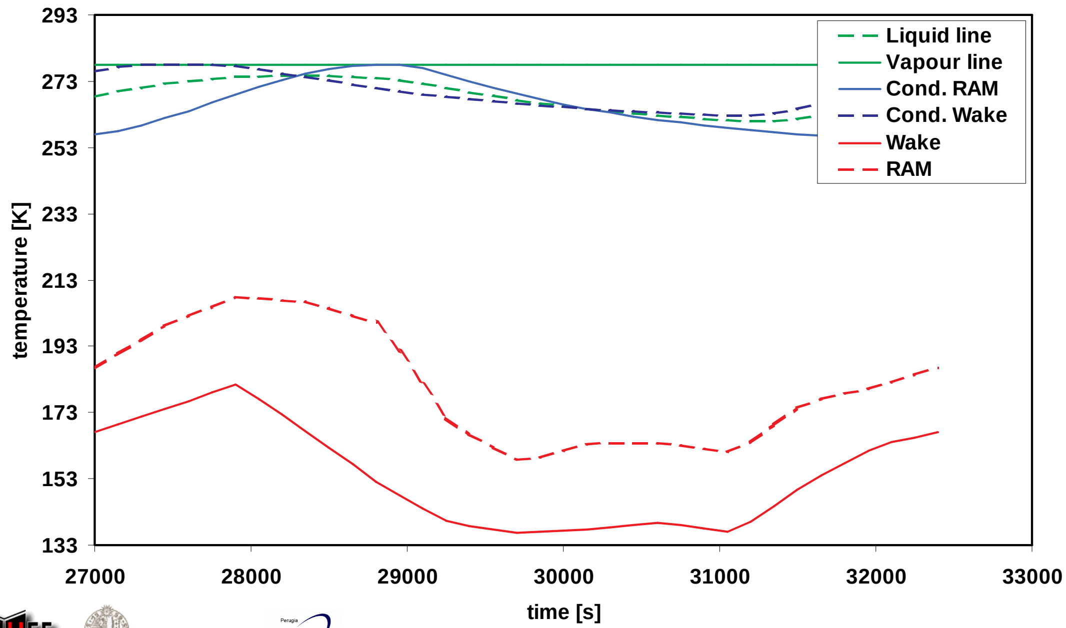
TTCS loop, typical result



β=0
MPA
flat radiator

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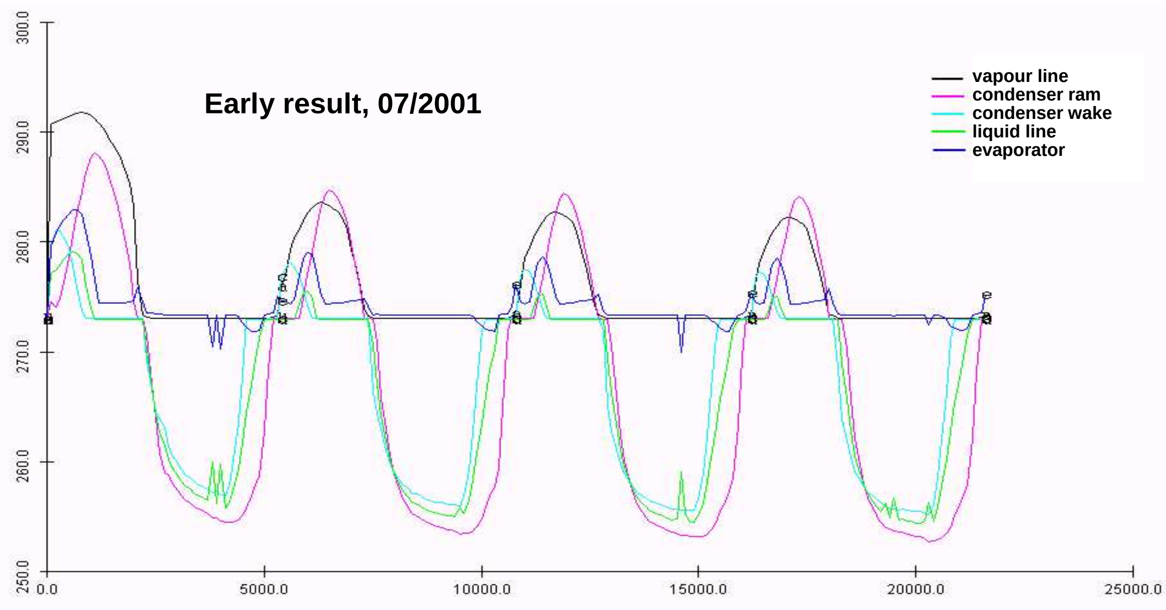
Radiator size, mass and shape



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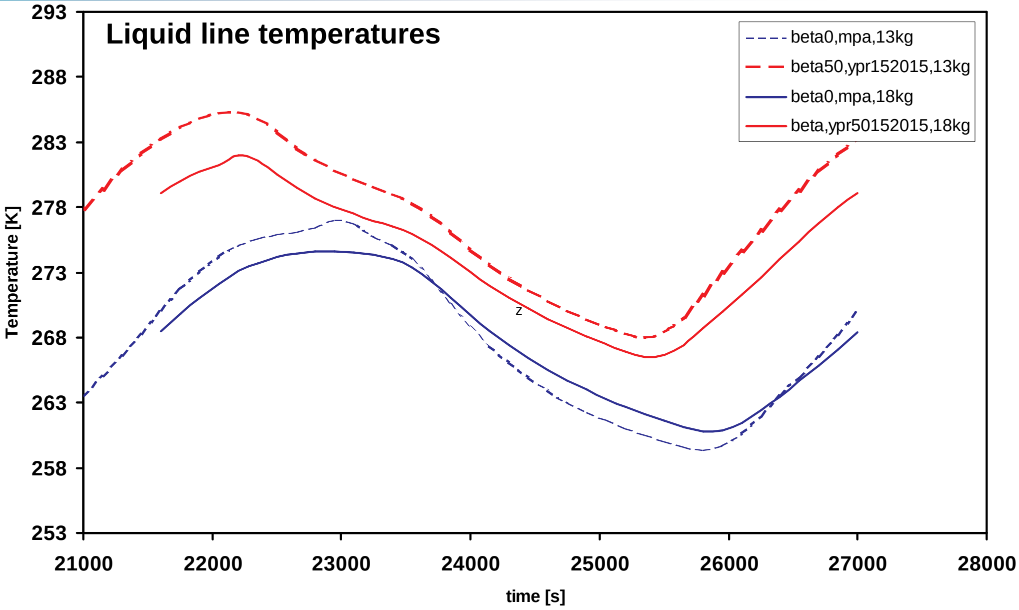
Radiator mass



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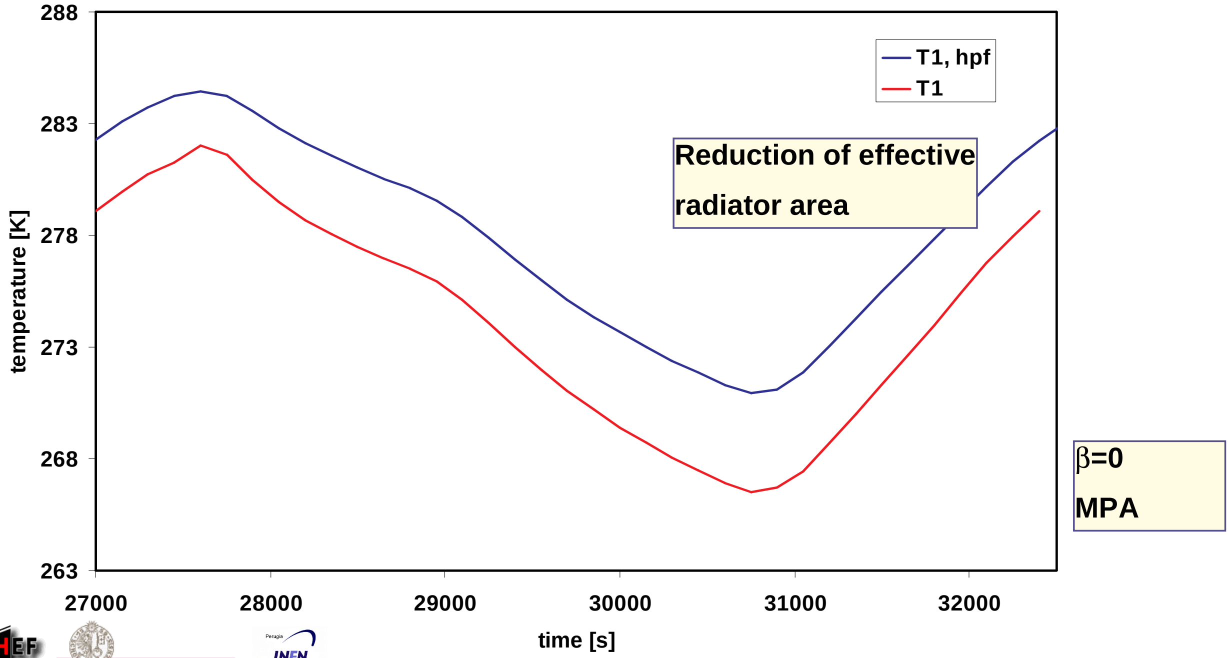
Radiator size: Heat pipe failure



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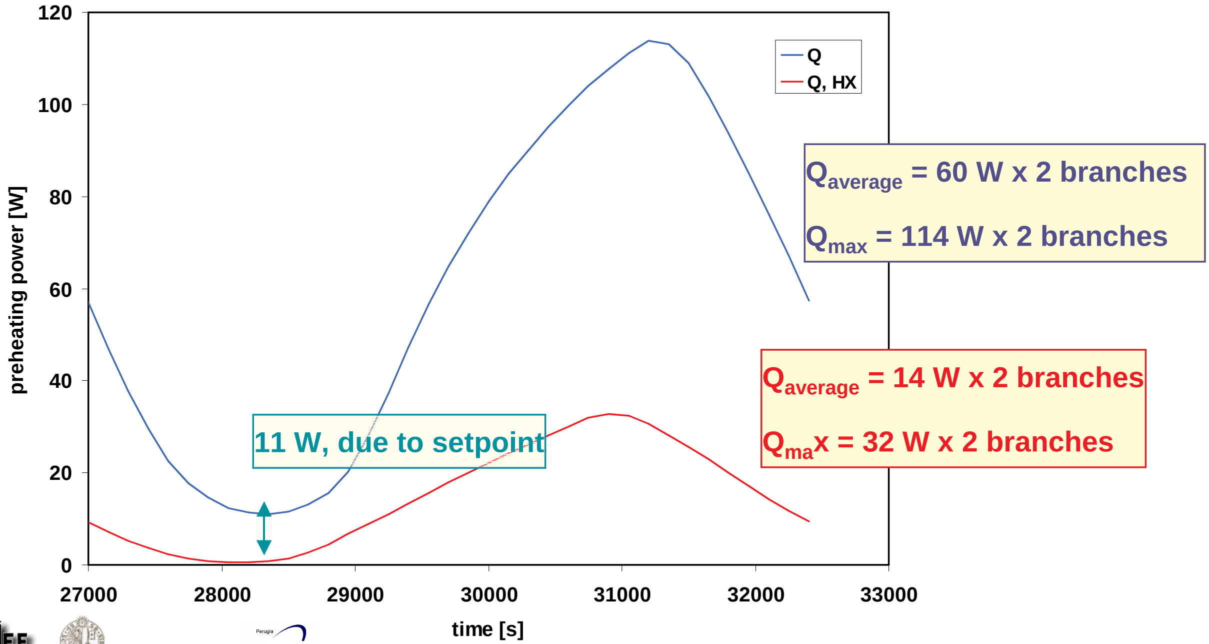
National Aerospace Laboratory NLR

Preheating



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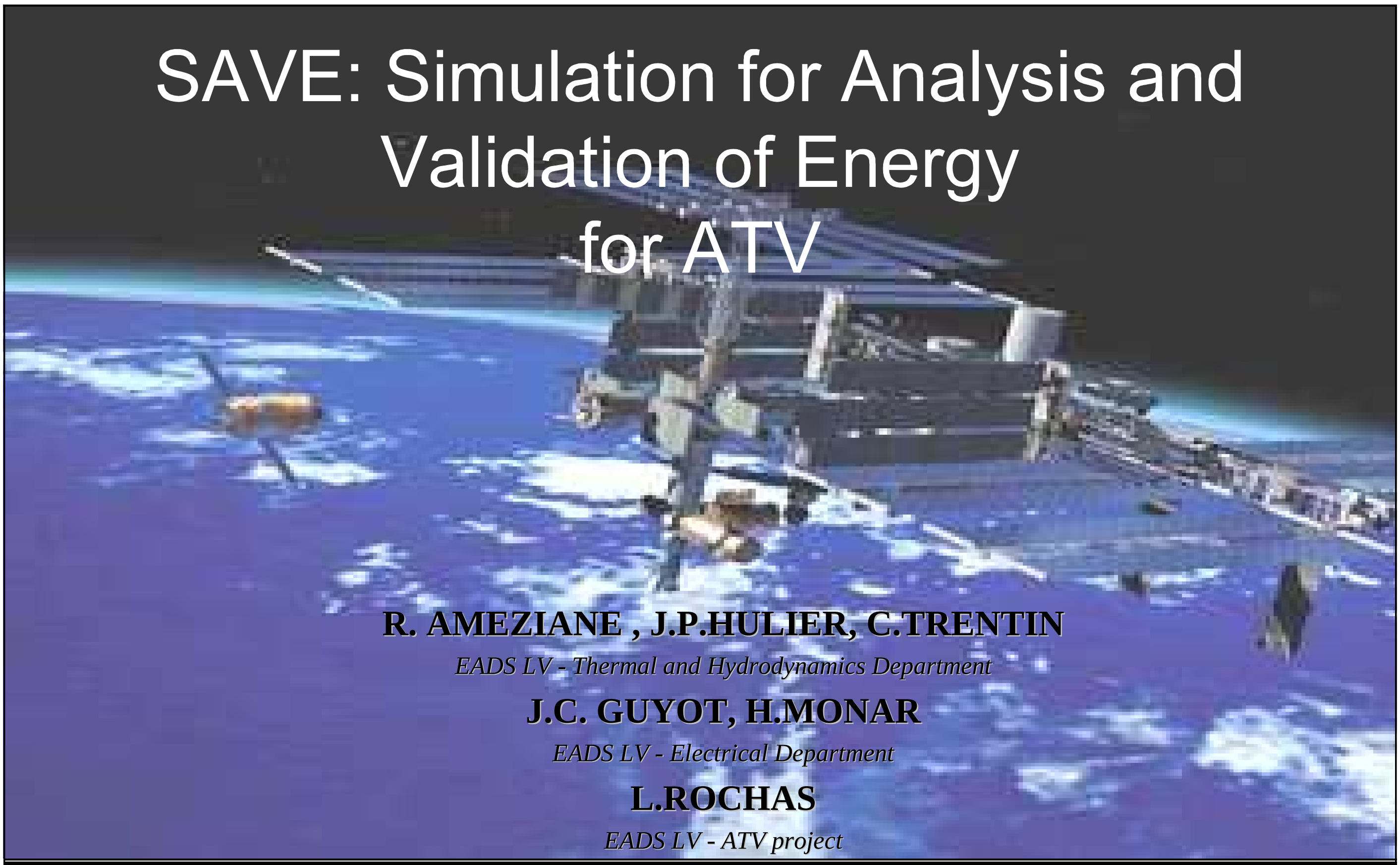
Conclusions

- **Feasibility of TTCS supported by numerical model**
- **Several design choices based on and supported by thermal modeling**
- **Proven to be an important tool in engineering discussions with AMS experimenters**

Appendix C: SAVE: Simulation for Analysis and Validation of Energy for ATV

SAVE:
Simulation for Analysis and
Validation of Energy
for ATV

R. Ameziane
EADS - Launch Vehicles



SAVE: Simulation for Analysis and Validation of Energy for ATV

R. AMEZIANE , J.P.HULIER, C.TRENTIN

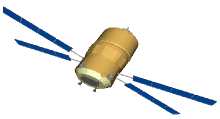
EADS LV - Thermal and Hydrodynamics Department

J.C. GUYOT, H.MONAR

EADS LV - Electrical Department

L.ROCHAS

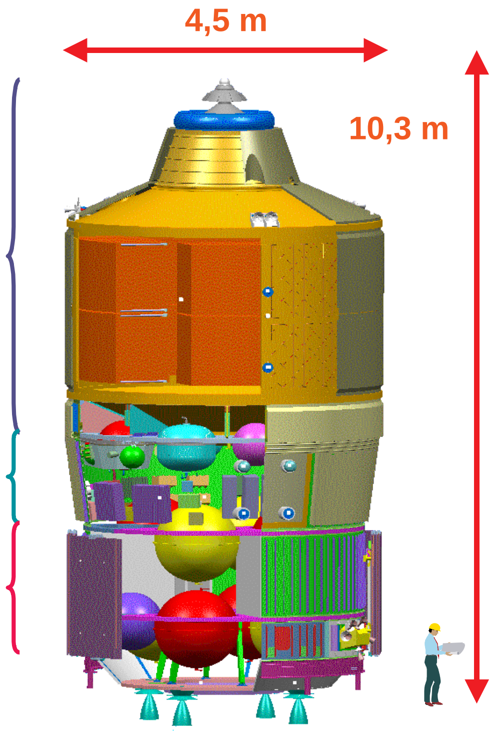
EADS LV - ATV project



SUMMARY

- The ATV project
- SAVE platform context
- SAVE platform overview
- SAVE Thermal Mathematical Model (STMM)
- STMM integration into SAVE
- Conclusion / Remarks

Automated Transfer Vehicle



First flight: mid 2004

Integrated Cargo Carrier (pressurised)

- supply for ISS crew: dry cargo
- water, gas

Equipped Avionics Bay (EAB)

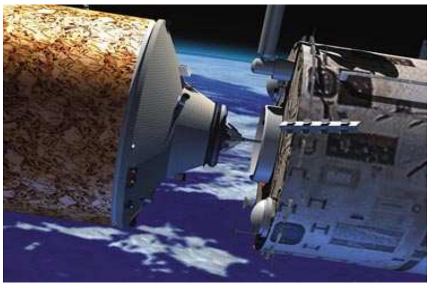
Avionics, batteries

Equipped Propulsion Bay

- propulsion for ATV
- ISS reboost

ATV mission

Phasing with ISS RDV with ISS



Docking

Docked

Launch - A5

6 months mission

- ISS orbit control
- ISS refuelling
- Retrieval of waste
- Destruction

ATV thermal control concept

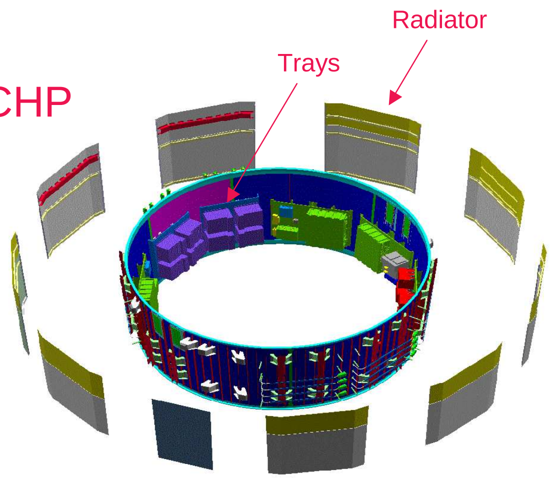
- Keep a “warm” EAB in cold phases
- Cool the EAB in warm phases

ACTIVE THERMAL CONTROL with VCHP

- 4 VCHP per trays
- 10 trays
- 10 AFCU: Active Fluidic Cooling Unit

3 WORKING MODES:

- OFF mode
- ON mode
- Control Conductance



Equipped Avionics Bay

SAVE platform

On-board <u>power users</u>:

- Equipment items
- Thermal control

Thermal control is the main user of the power (VCHP control, heated items)

⇒ A platform simulator has been developed to couple thermal and electrical aspects

⇒ SAVE^{mgt}: Simulation for Analysis and Validation of Energy management

⇒ Main software: SABER, used in electrical engineering

OBJECTIVE: to demonstrate on-board available power covers the vehicle needs

SAVE: main tool of the thermal/electrical coupling verification on ATV

SAVE Overview

SAVE integrates on-board prototype software:

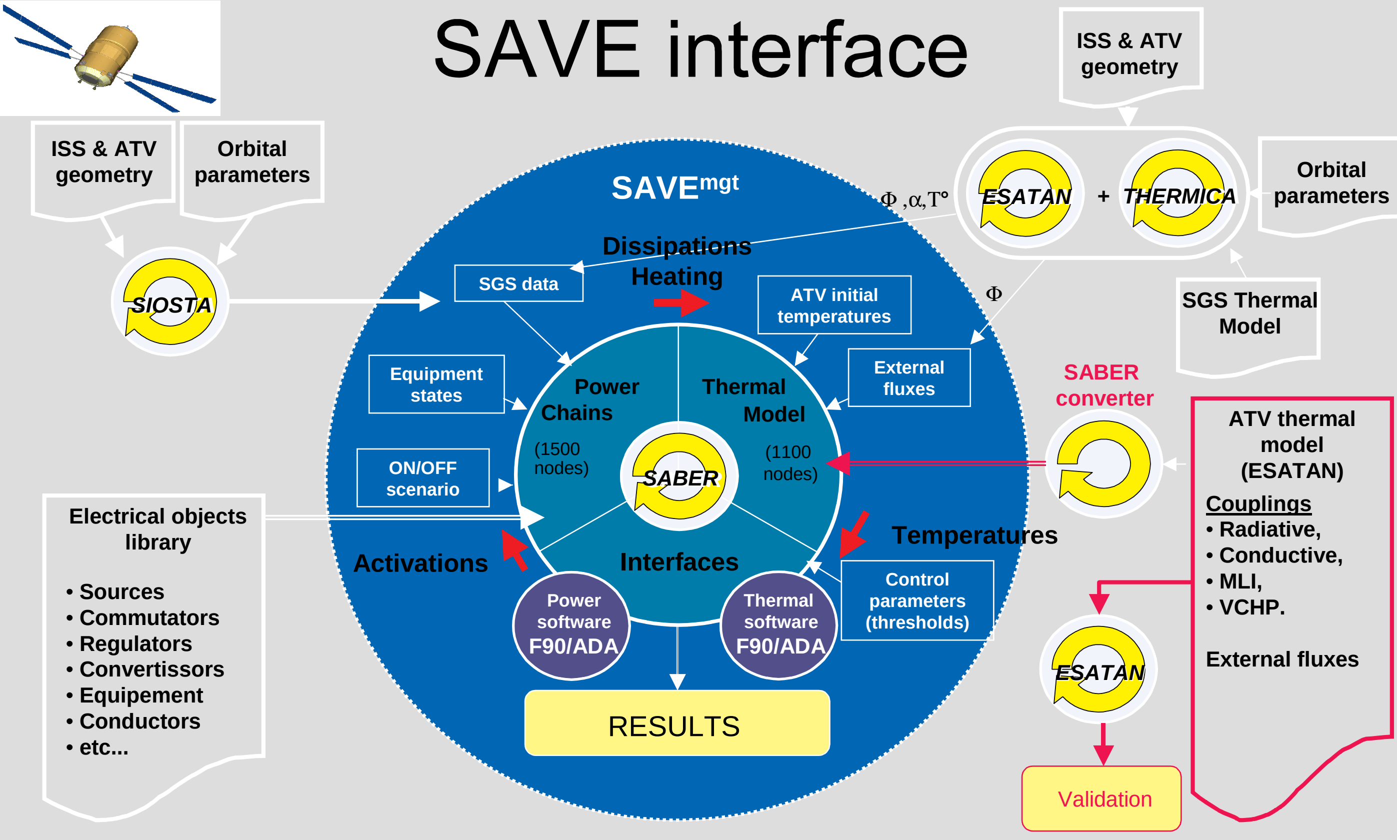
Thermal Control Chain Function Unit

- Controls the VCHP,
- Controls the heated items,
- Distributes the thermal control on the 4 power chains,
- Manages the day heating, Energy Saving,
- Prioritises the activation of heaters.

Power Supply Function Unit

- Manages the battery Depth Of Discharge,
- Prioritises the 4 power chains on board,
- Manages the solar arrays current,
- Manages the ISS power,
- Reduces the items power consumption in case of energy saving.

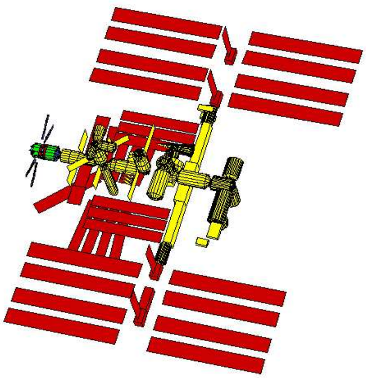
SAVE interface



ATV thermal model

STMM: Save Thermal Mathematical Model

Used software: ESATAN, THERMICA



≈ 20,000 Radiative couplings (compressed to ≈ 9 000 for time calculation)

≈ 1,300 Conductive couplings (constant or variable)

≈ 1,100 nodes with ISS

>300 internal dissipations

≈ 150 external fluxes

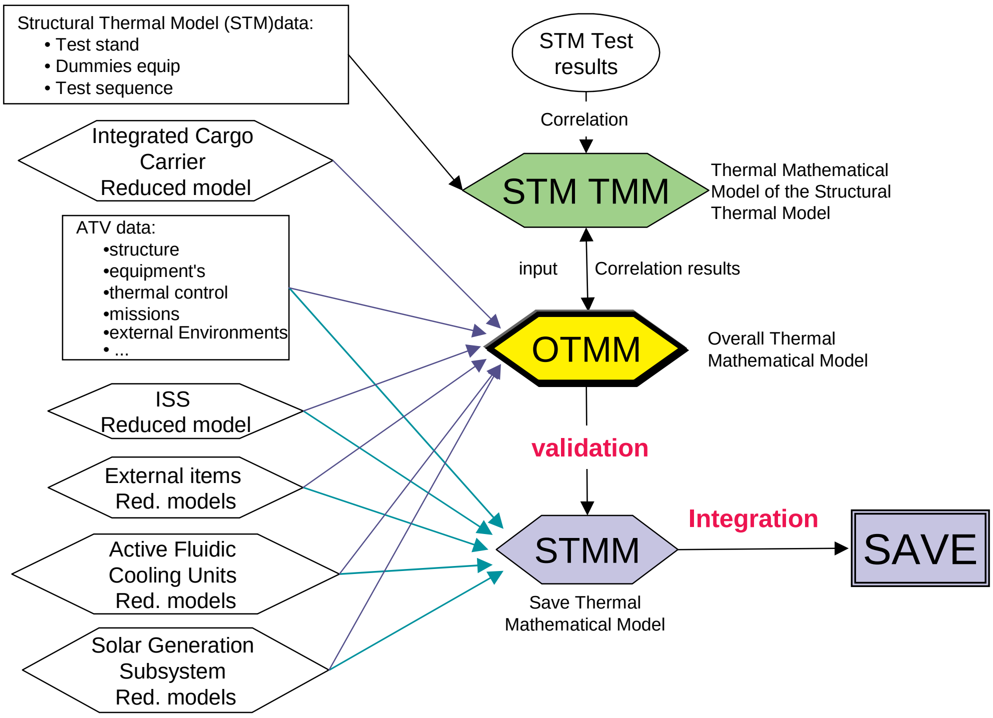
≈ 175 item temp. Heat balance

Thermal model Validation

Validation process before integration into the platform

- Validation on temperatures
- Validation on heat balance

Thermal model Validation



EADS LAUNCH VEHICLES

Thermal patch

Interfaces the thermal model with the platform
- SABER language
- Validates the thermal software

INPUTS:

dissipating nodes

Heated nodes

OUTPUTS:

Temperature nodes for thermal control (VCHP, heated items)

Thermal Patch

> Inputs and outputs

> Thermal Model: STMM

> External Environment

> Equations

ESATAN_to_SABER converter

Model in SABER

Radiative couplings

Conductive couplings

Capacitance…

BASE COMPONENT

Initial conditions

THERMICA_to_SABER converter

External fluxes

provided by THERMICA calculation

Fluxes resolution

EADS LAUNCH VEHICLES

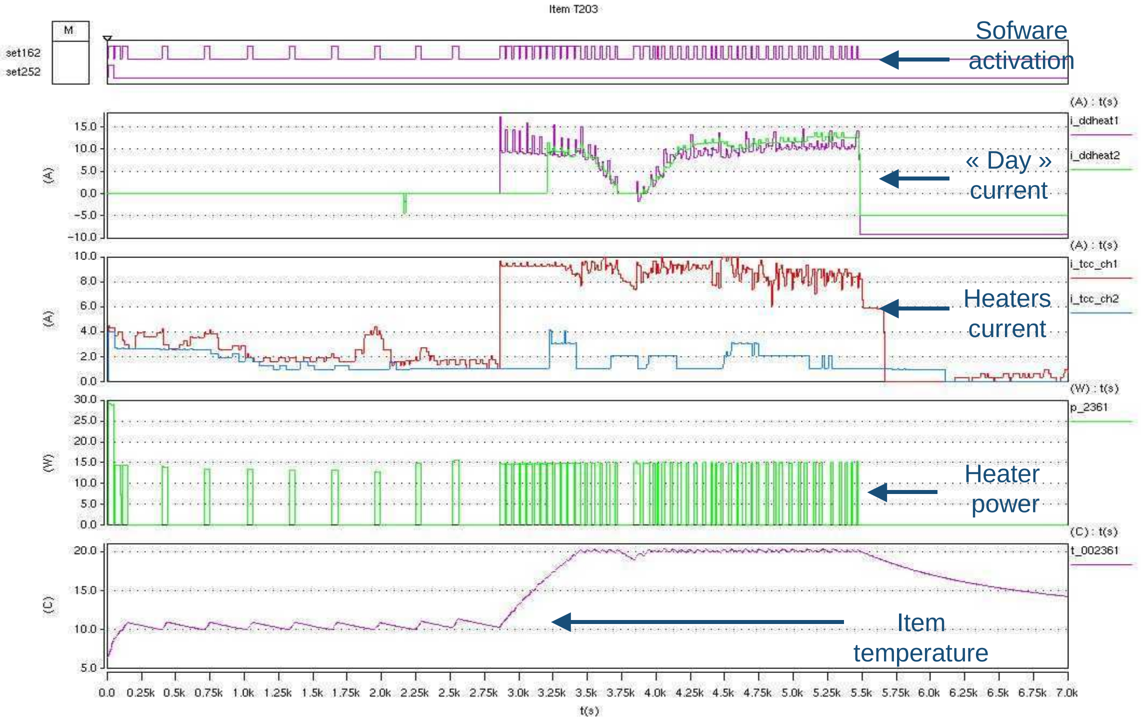
ESATAN_to_SABER converter

The converter translates the thermal model from ESATAN to SABER language

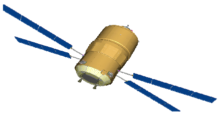
- Re-creation of SABER 'BASE COMPONENT' (for transparency)
  - to simulate radiative and conductive couplings
  - to simulate constant capacitance
- Creation of new base components
  - to simulate VCHP function
  - to simulate MLI efficiency variation
  - to simulate capacitance variation

VALIDATION OF EACH COMPONENT comparing ESATAN with SABER

SAVE results



EADS LAUNCH VEHICLES



Conclusion

- **First simulations have been performed in 2001 with a beta version**
- **Software (thermal control and power supply) has been introduced in 2002**

NEXT STEPS :

- **Validation of STMM with ATV system thermal tests results performed in 2002**
- **Algorithms prototypes validation**
- **Platform expected to be fully operational in June 2003**

Appendix D: Status of some ESA supported activities in thermal, thermo-hydraulic and ECLS analysis

Status of some
ESA supported activities in
thermal, thermo-hydraulic
and
ECLS analysis

O. Pin
ESTEC/TOS-MCV

Status of some ESA supported activities in thermal, thermo-hydraulic and ECLS analysis

Olivier PIN
ESA ESTEC
Thermal and Structures Division
Email: Olivier.Pin@esa.int

ESTEC
Thermal and Structures Division

Purpose: To brief you on some work that we have been carrying out and that we plan to initiate in the area of:

- **Thermal** analysis tools (ThermXL, ESATAN + new tools)
- **Thermo-hydraulic** analysis tools (FHTS, ALGOCAP)
- **ECLS** analysis tools (EcosimPro)
- **Distributed** simulation tools (DC using ESATAN as a server)
- **Methodologies** (stochastic approach, model reduction)

Activities related to ESARAD, Data Exchange, OSS applicability & Harmonisation are not treated here → For info: Hans Peter de Koning and/or Charles Stroom

Thermal analysis tools

ThermXL

(Industrial partners: ALSTOM & FSC)

Activities in 2001-2002:

- Functionality consolidation (slight issues from v1.0 corrected)
- Implementation of a new license mechanism
- New functionality provided with v2.0 (ESATAN/SINDA export, user results worksheet, API to execute solvers from VB etc.)
- Current developments include ESARAD import & sensitivity worksheet

See ALSTOM presentation for details

esa ESTEC
Thermal and Structures Division

Thermal analysis tools

Thermal Concept Design Tool

(ITT on EMITS beg. 2003)

- Intended as a specific environment to support pre-phase A, phase A & "what if" studies
- Will also be used for the ESTEC Concurrent Design Facility
  (ThermXL is currently used but lack high-level functionality)
  → probably built using Excel
- Pre-built and customised "design modules" to execute a sequence of "jobs" automatically and transparently
  Example: radiator sizing may require the generation and management of a GMM and a TMM but this will be hidden for the user who will work on a high-level
- The idea is to use & integrate existing tools

Thermal analysis tools

Thermal Concept Design Tool (cont.)

- Databases to quickly derive essential information
  Examples: thermo-optical properties, contact conductances,
  heat pipes / CPLs / LHPs conductances
- Standard mechanism to capture mission and temperature requirements
- Standard mechanism to feedback output of the thermal subsystem to other subsystems e.g. radiator areas, power budget
- To assess the possibility of building a “thermal design” database associated with mission type & spacecraft configurations

Thermal analysis tools

ESATAN

(Industrial partner: ALSTOM)

Activities in 2001-2002:

- Implementation of “simple” but useful functionalities requested for many years (cyclic solver, min/max routines etc.)
- Correction of a large number of bugs (> 20) that were making the users’ life difficult
- Implementation of FlexLM as a license mechanism
- New developments within v8.8 (fast-ESATAN, common block interface for nodal entities, heat balance convergence criteria, consolidation of user documentation etc.)

See ALSTOM presentation for details

Thermal analysis tools

Open Source Post-Processing Tool for Thermal Data Using STEP/NRF

(Industrial Partners: ALSTOM + Consortium of users)

- Expected to be carried out by ALSTOM + Users (CNES + Primes + Subcontractors + Academia). Planned for mid. 2003
- Has been requested by the user community for many years as a key tool to complement the current suite
- The term "post-processing" <u>has many meanings</u> and can include different aspects such as plotting, heat balance inspection, support for test preparation/correlation, data model traceability through the life cycle of the analysis etc.
- Considerable resources have been deployed to develop specific & strategic functionality by Industry & Agencies.
  An open framework should thus be provided

Thermal analysis tools

Open Source Post-Processing Tool for Thermal Data Using STEP/NRF (cont.)

- 2 levels of functionality:
  - Standard: API for database access using a STEP-NRF data model, plotting, comparison between analysis/test results, support for test engineering
  - Customised: To fulfill specific / proprietary needs of the users e.g. different model reduction algorithms modules
    that can be plugged-in to the environment
- Pilot project for the OSS approach. The IPR will belong to ESA (one-off development)

Thermo-hydraulic analysis tools

FHTS

(Industrial partner: ALSTOM)

Activities in 2001-2002:

- Review of current mechanisms provided to define and use fluids properties and heat transfer correlations
- Correction of bugs as for ESATAN
- New functionality under investigation in response to request from Industry e.g. zero-flow solution for ALENIA
- Prototyping of FGENFI (two-phase transient solver) to support fluid in pseudo steady-state and improve performance

See ALSTOM presentation for details

esa ESTEC
Thermal and Structures Division

Thermo-hydraulic analysis tools

ALGOCAP

(Industrial partner: OHB)

Activities in 2001-2002:

- Bibliographical review of algorithms used for the design and analysis of CPLs and LHPs
- Prototyping activities to investigate CPLs/LHPs simulation at system-level with a thermal solver (e.g. ESATAN) and without inside knowledge of the fluid loop components
- Executive report will be available soon

See OHB presentation for details

ECLS analysis tools

EcosimPro

(Industrial partner: Empresarios Agrupados)

Activities in 2001-2002:

- Version 3.2 with post-processing (plotting & roll-back), dependency tree, better integration with Smartsketck
- Independent industrial assessment of Astrium-GmbH (RFR project) → EcosimPro to replace PC ESATAN for ARES activities (see also the Astrium presentation at ICES 2002)
- New libraries for ECLS (MELISSA – see A. Rodriguez's presentation) and non ECLS activities (dedicated library for the ESTEC Propulsion Division)

Distributed simulation tools

DC & using ESATAN as a server

(D. Alsina Orra, YGT at ESTEC + FSC + Simulation Section)

- Requirement for loose and distributed coupling of 2 or more applications (client-server approach)
  <u>Examples</u>: e.g. ECLS simulation requiring the use of an ESATAN model (ISS) or plug-in of thermal models in real-time simulators
- DC (using TCP/IP) was developed by FSC and released to ESA with Fortran 77, C, C++ APIs in 1997. (Had been little used since).
- D. Alsina's assessment of off-the-shelf technologies has lead to adapt DC and carry out prototyping tasks

Distributed simulation tools

DC & using ESATAN as a server (cont.)

- Prototyping activities performed at ESTEC:
  - Distributed coupling of 2 ESATAN models on 2 platforms (SGI / Linux)
  - Encapsulation of the ATV thermal model in an EcosimPro component for system analysis (usage of ESATAN is transparent for the user). ESATAN ran on Linux and EcosimPro on PCWindows/NT
  - Plug-in of the SMART-1 & ATV models to Eurosim to assess feasibility of real-time simulation (some limitations were found but were not DC-related)

Distributed simulation tools

DC & using ESATAN as a server (cont.)

- Continuation of prototyping tasks with implementation of a SOAP interface to pass firewalls
- Assessment to see if, in addition to ESA tools, DC can be provided at the lowest possible cost

Questions: 1. Is there some interest for such a tool?

2. Which company would be happy to test it?

Methodologies

Using a stochastic approach for thermal analysis

(ITT closed and consortium selected – Kick-off Nov. 2003)

- Develop a methodology based on the use of stochastic techniques to support the thermal analysis through the entire lifecycle of the TCS
- Selection of COTS or/and small software development
- Thorough assessment on practical and industrial cases
- A key aspect is to provide full visibility to the user community on the results obtained e.g. the Handbook is a key deliverable

Methodologies

Model reduction algorithms

(S. Appel + O. Pin, ESTEC)

- Review of “physical” and “mathematical” algorithms used to generate interface thermal models for inclusion at higher-level (little has been published on the subject)
- Preliminary internal activities based on algorithms used in structural analysis (static reduction) with possibility to eliminate or/and to aggregate nodes

  → Seems to work well both for steady-state and transient. May produce GLs < 0 when aggregating nodes
- There seems to be as many opinions on the subject as users! The best way forward is unclear. Any suggestions?

Appendix E: Modelling the VISTA Infrared Camera

Modelling
the
VISTA
Infrared Camera

N. Cavan
RAL

Modelling the VISTA Infrared Camera

16th ECLS Workshop, ESTEC

October 2002

Feedback from User Experiences of ESARAD 5.1.3 and ESATAN at RAL from the VISTA project

Nick Cavan: Tel: +44 (0)1235 778016
Fax: +44 (0)1235 445848
e-mail: n.j.cavan@rl.ac.uk
http://www.sstd.rl.ac.uk

Rutherford Appleton Laboratory

Modelling the VISTA Infrared Camera

16th ECLS Workshop, ESTEC

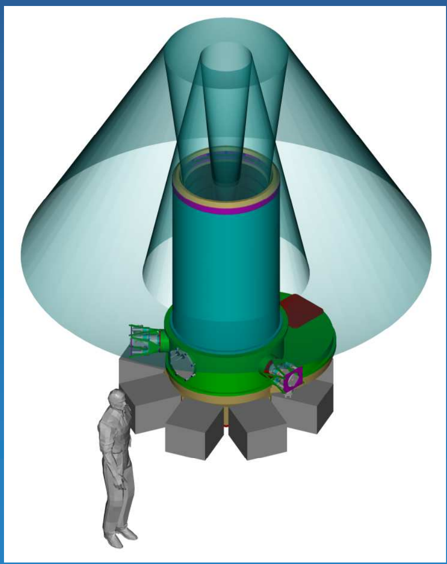
October 2002

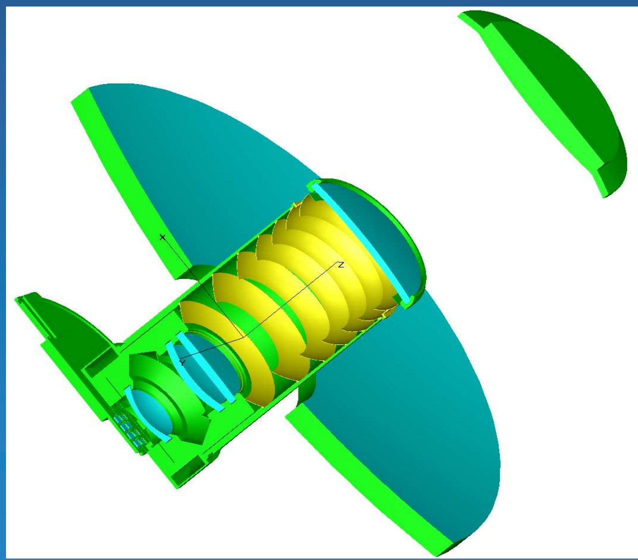
This presentation briefly covers

- An overview of the VISTA telescope and IR Camera
- A summary of the thermal modelling
- Feedback on our experiences of using ESARAD 5.1.3 and ESATAN for this project (and others)

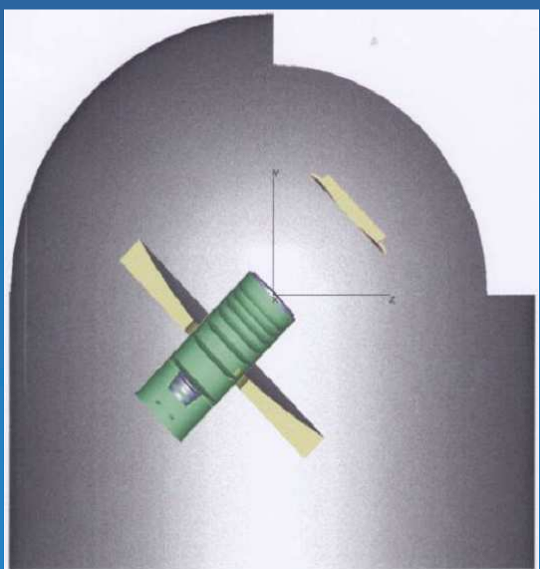
Rutherford Appleton Laboratory

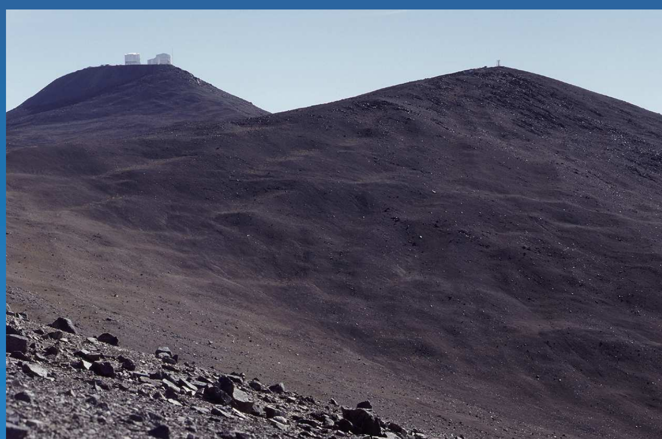
Visible and Infrared Survey Telescope for Astronomy





The VISTA IR Camera forms part of the UK contribution to the European Southern Observatory





Cerro Paranal, Chile; alt 4200m

Interesting Features

- Detectors 77K
- Cryostat internal structure < 190K
- Structure visible from detectors <120K
- Mass 2700 kg
- Detector dissipation 160mW plus 10W 'warm' electronics
- Heat lift required, 220W at 80K. Provided by 3 Gifford/McMahon cryocoolers
- Power, no limit (not specified), about 30kW
- LN_2 only available for cool-down (need 1200 litres)
- No MLI
- Service interval, 12months
- Design / Analysis currently on-going

VISTA IR Camera
Modelling the VISTA Infrared Camera
16th ECLS Workshop, ESTEC
October 2002

Summary of Thermal Modelling

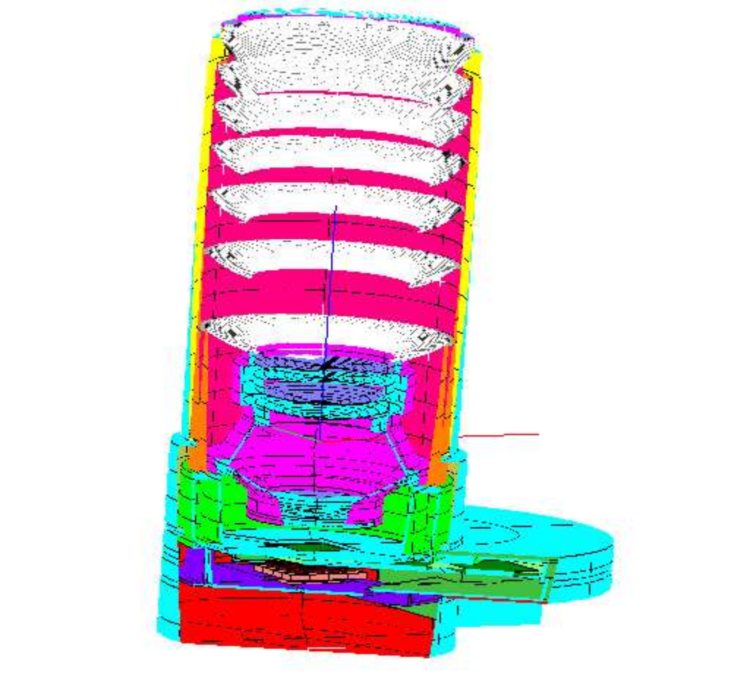
- ESARAD and ESATAN exclusively used
- Pentium 4 PC for ESARAD
  Sun Workstation for ESATAN
- Model size;
  2600 Nodes
  310,000 GRs, 5500GLs
  Temperature dependent properties used throughout
- Coolers modelled as boundaries with temperatures dependent on heat load.

CLRC Rutherford Appleton Laboratory

Modelling the VISTA Infrared Camera

16th ECLS Workshop, ESTEC

October 2002



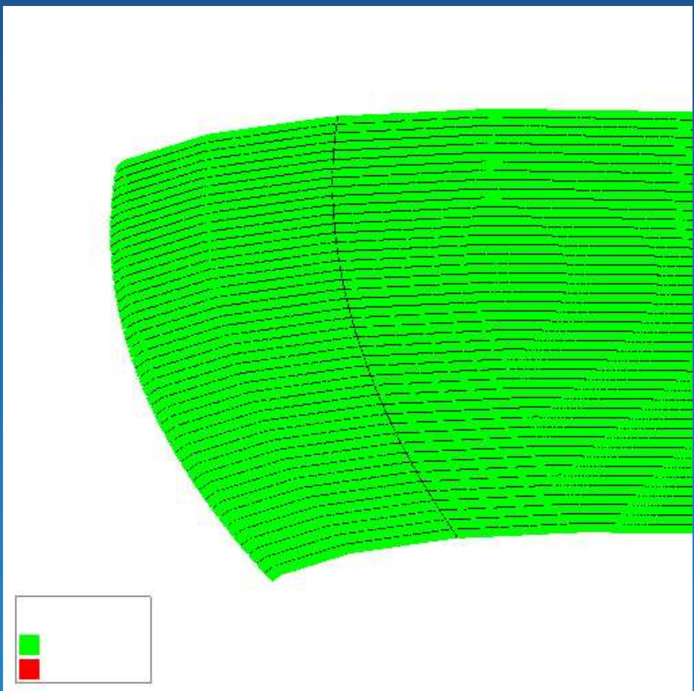
ESARAD Model of VISTA Camera

Rutherford Appleton Laboratory

Modelling the VISTA Infrared Camera

16th ECLS Workshop, ESTEC

October 2002



Ellipsoidal baffles each constructed from 45 ‘linked’ CONEs

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Comments relating to ESARAD 5.1.3

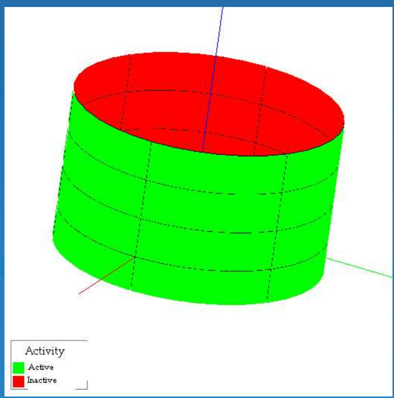
- The text edit mode is a real improvement to productivity
- The introduction of Analysis Case and the generation of the ESATAN input file is good and easy to use
- The display of pointing vectors and rotation axes for assemblies is very helpful; primary and secondary axes could have different colours
- Animation of the mission within the visualisation module is very useful
- It doesn't always start!

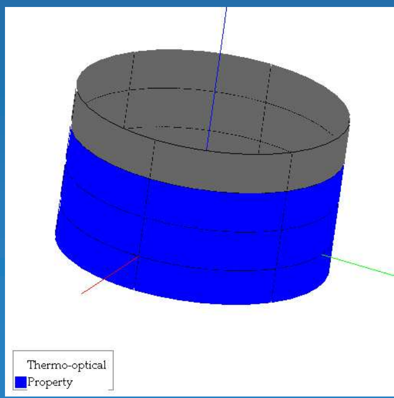
With the text edit mode a number of productivity issues arise

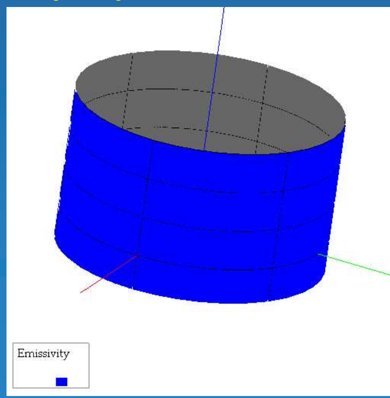
- 'Re-loading' the geometry causes all the radiative case and analysis case definitions to be deleted as well as deleting any calculated results.
- Updating a radiative case definition automatically deletes any existing results.
  Again, the user should have the choice to delete, or to keep existing results 'marked' as 'inconsistent'

A number of small ‘productivity’ problems still remain

- When transforming a shell rotations can only be about the SCS. For anything other than simple rotations this is ‘so less than intuitive’ that it is rarely used. Use of intermediate axes would solve this.
- Visualisation of active shells with undefined properties!







IR Camera

Modelling the VISTA Infrared Camera

16th ECLS Workshop, ESTEC

October 2002

Suggestions for ESARAD future developments and/or productivity improvements

On a minor scale,

- A new shell; surface of rotation based on a equation of a line, especially important for antennas and reflectors
- For ‘fixed’ geometries can the ‘GRs’ calculated for one radiative case be used for others.
- Memory leaks when outputting ESATAN file in analysis cases
- ESARAD to use node numbers up to 10 digits to make it consistent with ESATAN
- Reporting the orbit β-angle would be very useful
- Angle of incidence dependent optical properties

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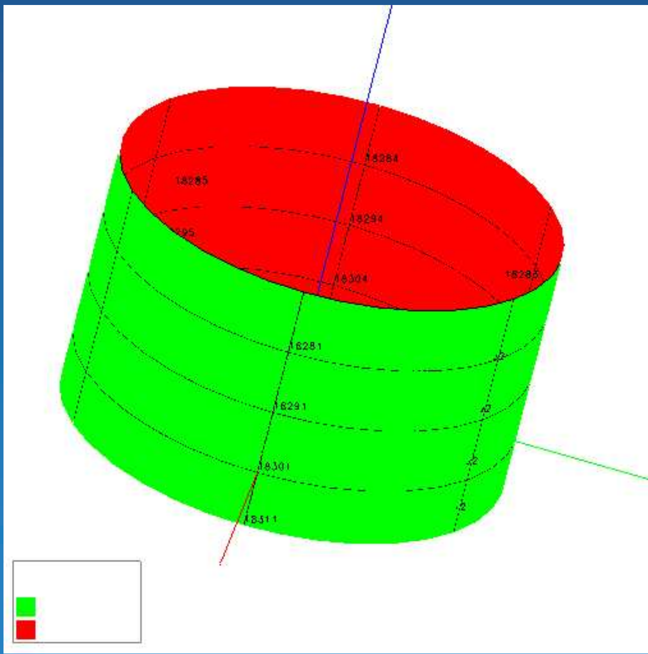

Improved Node Numbering

- Node numbering on a shell is always sequential.
- It would be useful to ‘step’ between ‘rows’ or ‘rings’.
- The model shown could then be modelled using 1 shell rather than 4.

IR Camera

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ESATAN is mature and stable.

It would be improved further by

- Limiting temperature minima to absolute zero within the solution routine (SOLVFM and others?). Temperatures of -9000°C were initially output, followed by >10E10°C when cryocooler heat lift was simulated.
- Inform users of the differences/limitations between PcESATAN and the UNIX version. GNU compiler appears to be limiting

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Future developments

- Automatic conductor generation, what's happening?
- Missions, when will there be improvements to
  - more intuitive main body pointing?
  - definition of the mission as an orbital arc or series of arcs (ie not necessarily a complete orbit)?
- Link to CAD/FEA tools. There is a strong link between CAD tools and structural tools but no link to ESARAD. This would represent the single most important development to 'our' tools

Appendix F: Thermal Analysis of Planck HFI

Thermal Analysis
of
Planck HFI

J. Fereday
RAL

Thermal Analysis of Planck HFI

16th European Workshop on Thermal and ECLS Software
ESTEC, 22-23 October 2002

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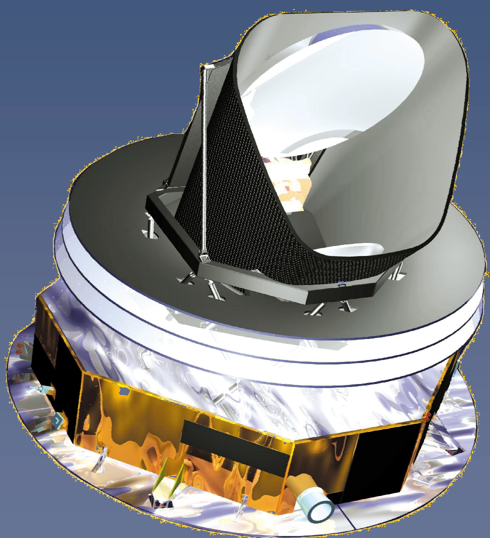
SUMMARY

- Planck mission overview
- Thermal design concept
- Systematic effects
- Global thermal model
- Radiative transfer model
- Thermal analysis issues

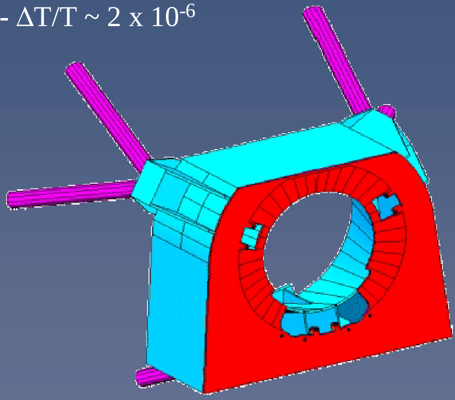


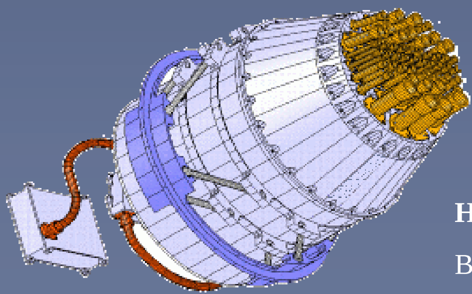
PLANCK MISSION OVERVIEW

3rd medium-sized mission of ESA's Horizon 2000 scientific programme
Testing theories of the early universe and the origin of cosmic structure
Measuring anisotropies in the Cosmic Microwave Background - $\Delta T/T \sim 2 \times 10^{-6}$

LFI (30 - 100GHz)

Tuned radio receiver array at 20K





HFI (100 - 850GHz)

Bolometer arrays at 100mK

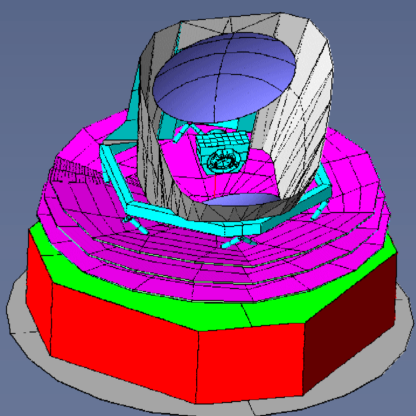
THERMAL DESIGN CONCEPT (1)

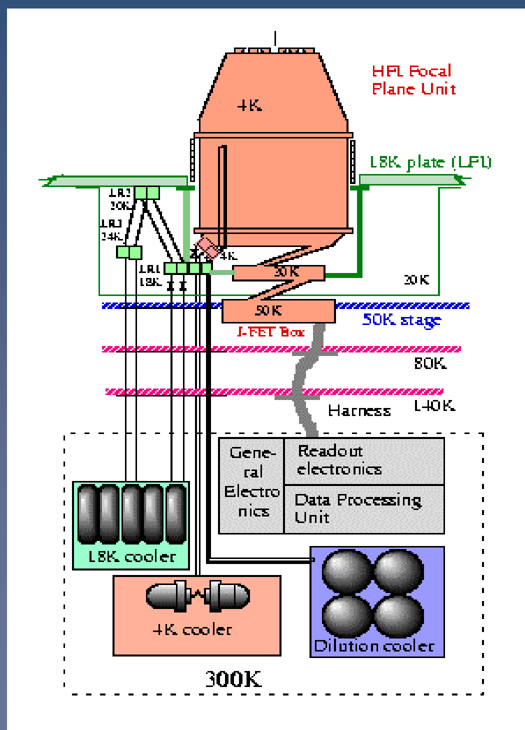
Passive cooling to 50/60K
- 3 v-groove shields to maximise radiation to space

JPL sorption cooler to ~20K
- cools LFI and HFI precooling stage
- thermally sunk to v-groove shields

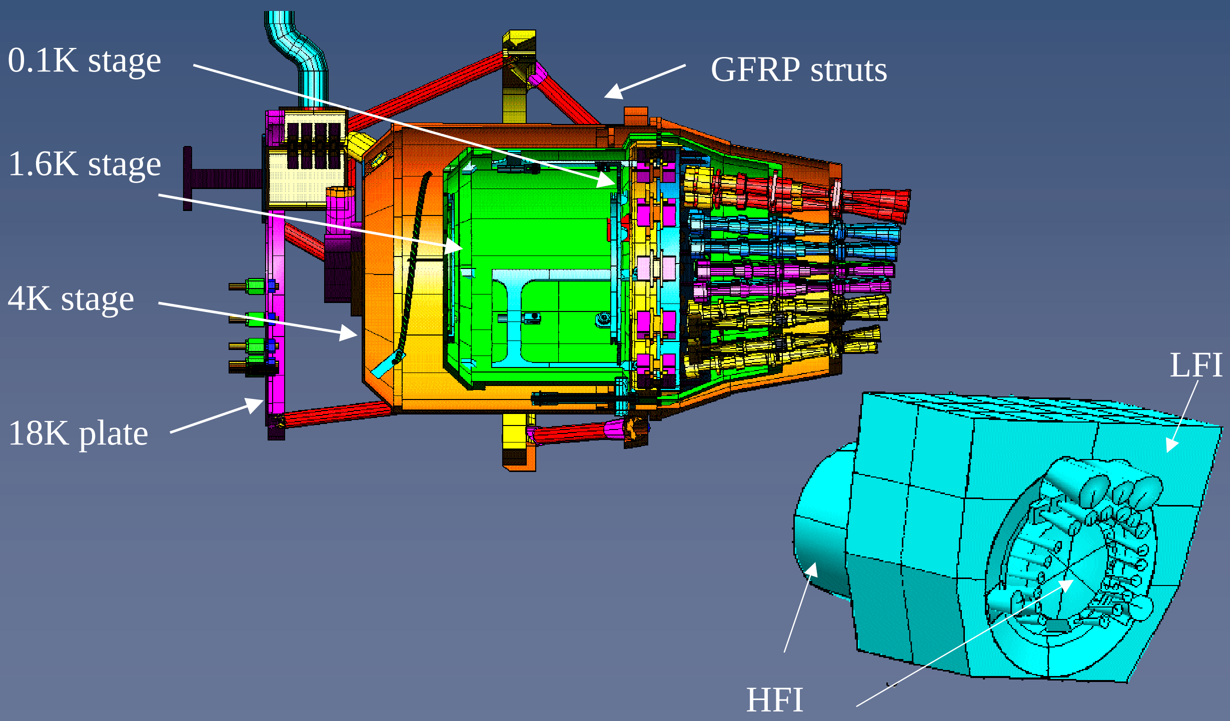
RAL 4K JT cooler
- precooling at 18K

Dilution refrigerator to 100mK
- precooling at 1.6K





THERMAL DESIGN CONCEPT (2)



SYSTEMATIC EFFECTS

Work done as part of ESA's Systematic Effects Working Group (SEWG)

Observations must be corrected for the effects of detector noise and layers of intervening material

Bolometer performance highly dependent on absolute temperature and temperature stability

⇒ Stringent stability requirements (e.g. bolometers < 19 nK.Hz$^{-0.5}$)

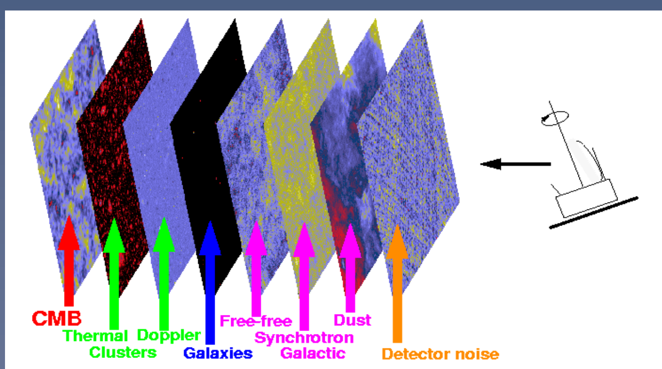
⇒ System level analysis needed – detailed understanding of fluctuations

⇒ Interaction between instruments, spacecraft and coolers is complex

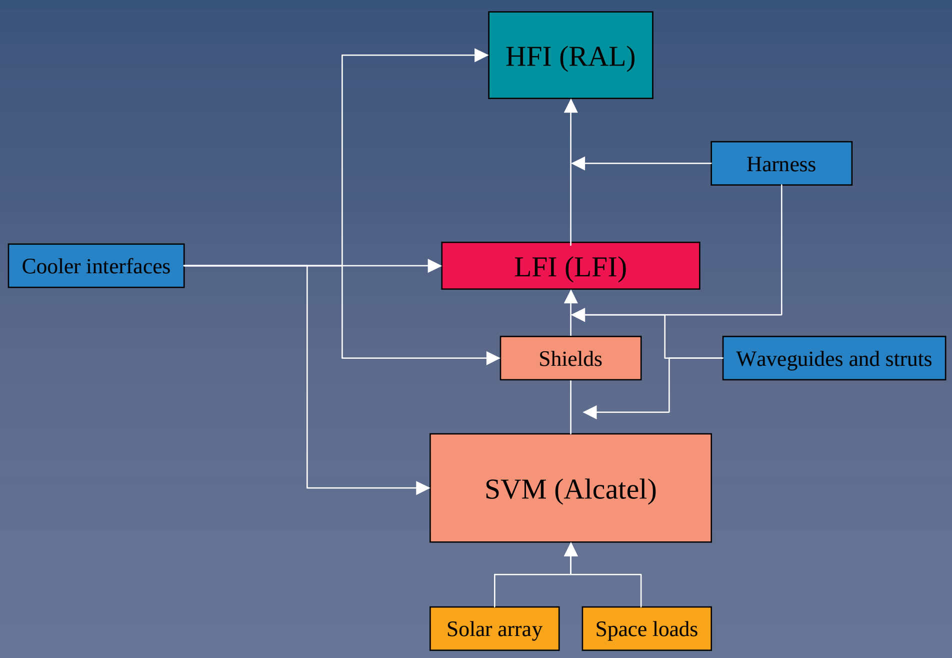
⇒ End to end modelling vital

⇒ Global thermal model created

⇒ Used to assess stability issues by providing full feedback loops to all spacecraft elements



GLOBAL THERMAL MODEL



SOURCES OF INSTABILITY

Operational environment
- L2 position and orbit - scanning/spin

Coolers
- Sorption cycling
- JT instabilities
- Effect of JT getter temperature being raised

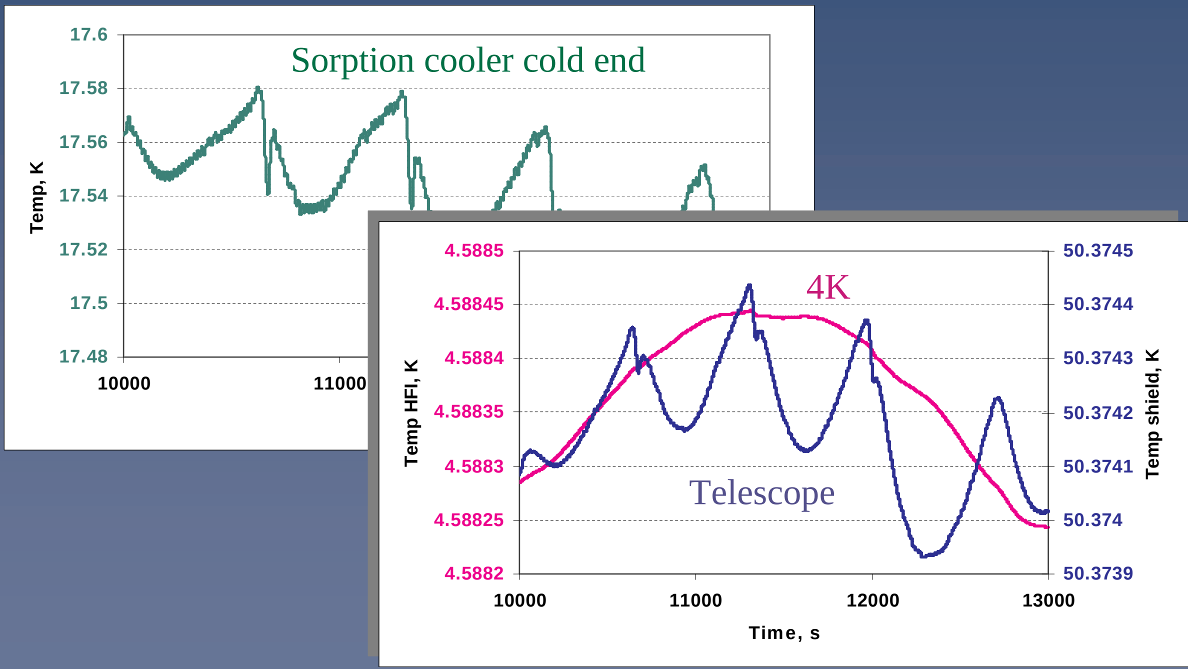
General
- Electronics switching
- Influence of 3rd V-groove temperature on LFI
- Influence of LFI temperature on HFI

Combined effects

Stability of sorption cooler identified as largest source

SORPTION SIMULATIONS RESULTS

PLANCK



RADIATIVE TRANSFER MODEL

PLANCK

AIM: To produce a modelled detector output, including noise, to be used for the "removal of systematic effects"

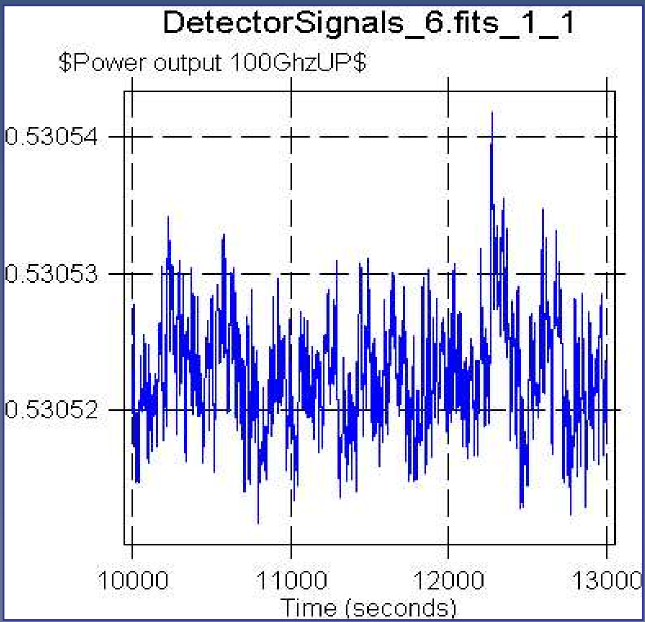
INPUTS: Simulated sky Time Ordered Data (TOD)
TOD of the thermal variations of critical nodes in the HFI.

Model received showing bolometer performance against thermal behaviour
- supplied in MathCAD format
- produces bolometer output power, taking into account system noise
- originally took constant temperature as an input
- modified to accept arrays of thermal fluctuation data

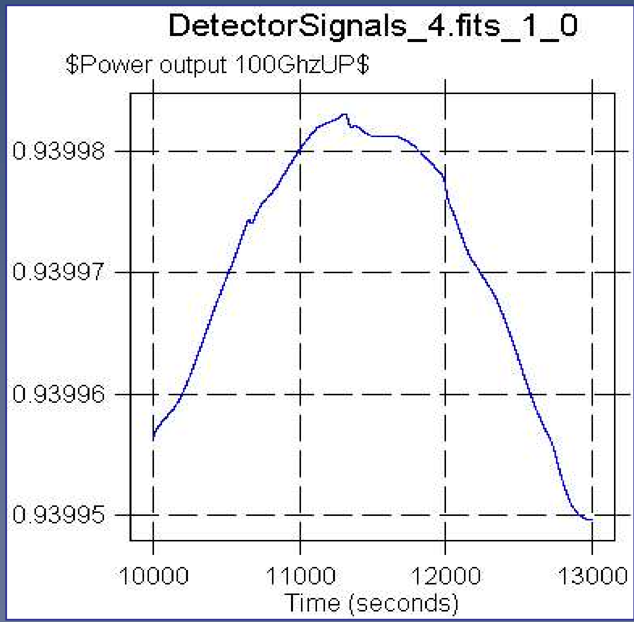
Excel used originally
- MathCAD add-in
- macros used to feed thermal model output data into model
- run time and file size became restrictive very quickly

MathCAD model re-written in C++
C++ command line model now used that enables sky data and thermal data files to be input in batches

TRANSFER MODEL OUTPUT

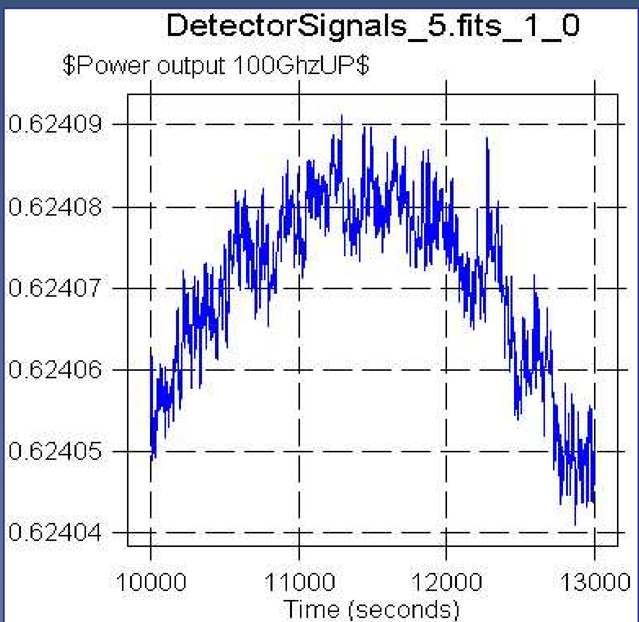


Detected Model Sky at 100GHz with Stable 4K



Power on Detector from Temp Fluctuations and 'Constant' Sky

TRANSFER MODEL OUTPUT



Detected Model Sky at 100GHz with Temperature Fluctuations

THERMAL ANALYSIS ISSUES

Run time

- Sorption cooler data sets 40,000s
- 1/3s data output required
- Convergence criteria must be high
- Constants material properties used where possible
- Nodes set to boundary temperatures where possible

Format compatibility

- Thermal model in ESATAN – output to .csv files
- Sky TOD in FITS format
- Bolometer model in MathCAD

Configuration control

- Several different models required – cooldown, cooler failure cases, stability cases
- $INCLUDE function used whenever possible to ensure model update is easy – ‘plug in’ modules

Appendix G: ESARAD v-5.1

ESARAD
v-5.1

F. du Laurens d'Oiselay
Alstom

October 2002

ESARAD v-5.1

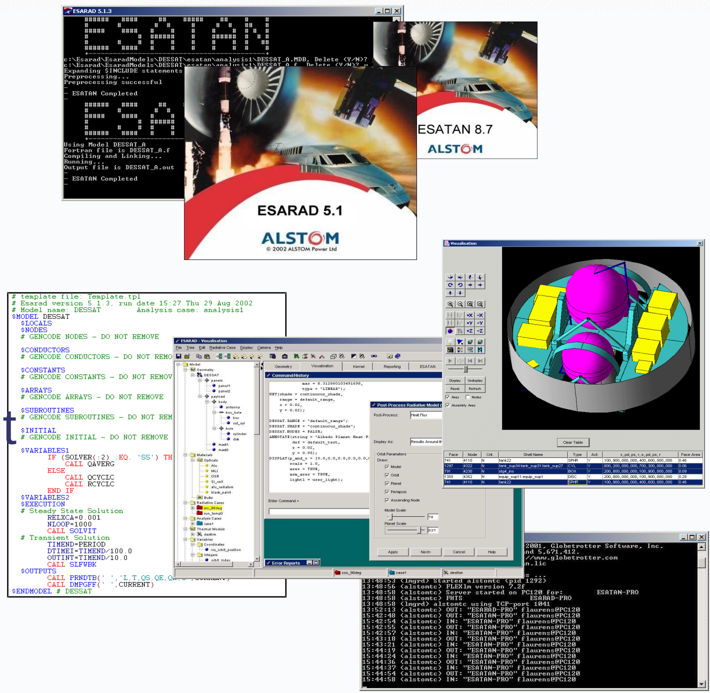
Frédéric du Laurens

ALSTOM

ESARAD v-5.1

ALSTOM

- List of new features
  - ESATAN interface
  - GUI and Visualisation
  - Analysis case
  - Text edit mode
  - FLEXlm
- Tips to make the best out of them
- Short demo if time permitting

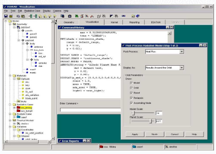
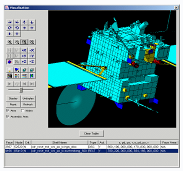
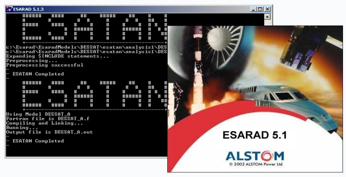


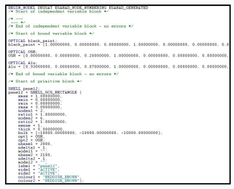
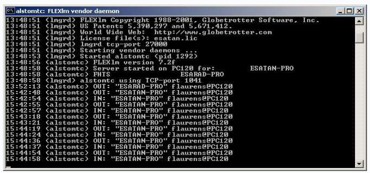
- Objectives -

ESARAD v-5.1

ALSTOM

New features

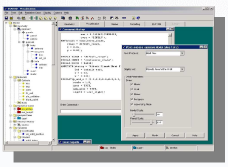
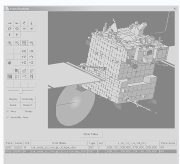
- GUI
- Visualisation
- ESATAN integration
- Text edit mode
- License mechanism

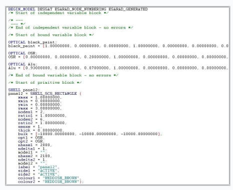
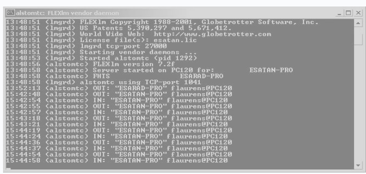
- Summary -

ESARAD v-5.1

ALSTOM

New features

- GUI
- Visualisation
- ESATAN integration
- Text edit mode
- License mechanism

- Summary -

GUI

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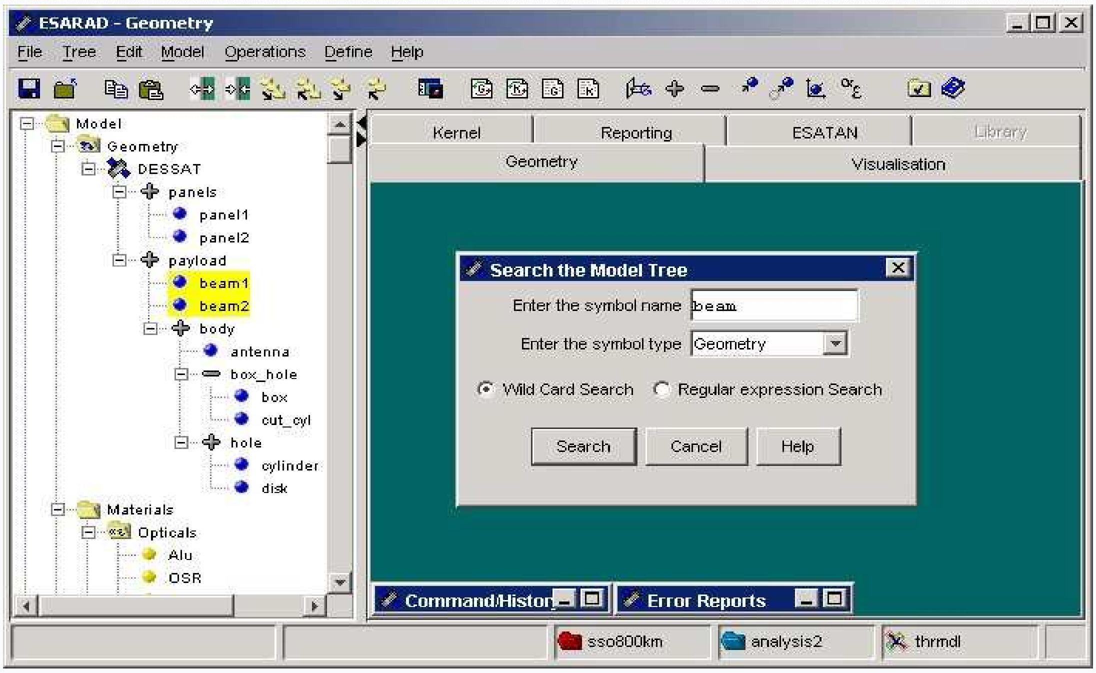


- Tree Search -

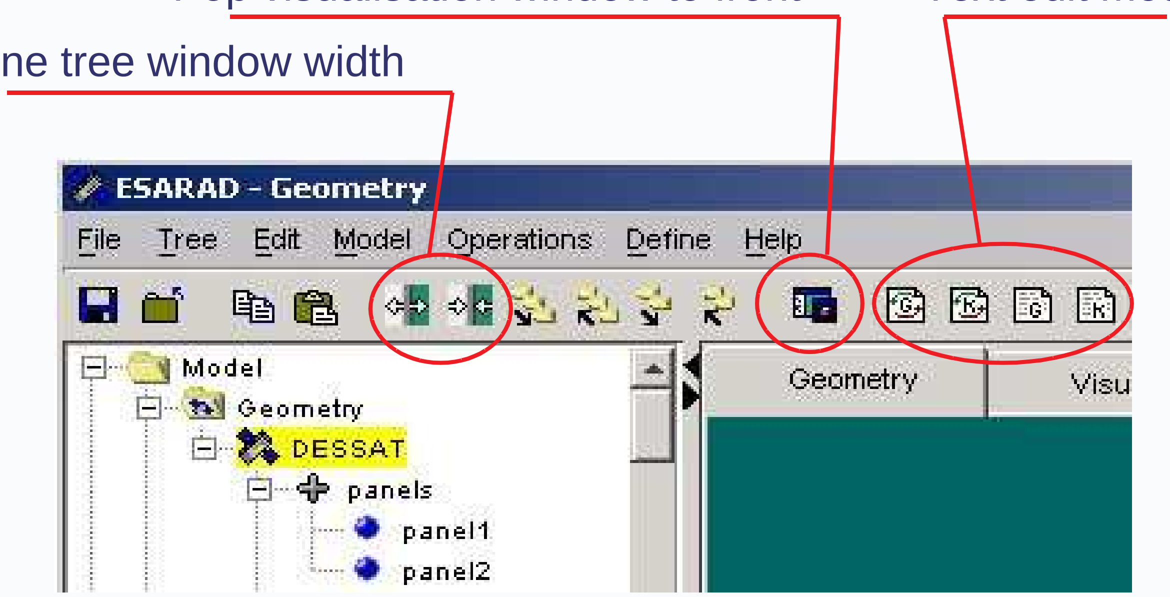
GUI

ALSTOM

Pop visualisation window to front

Text edit mode

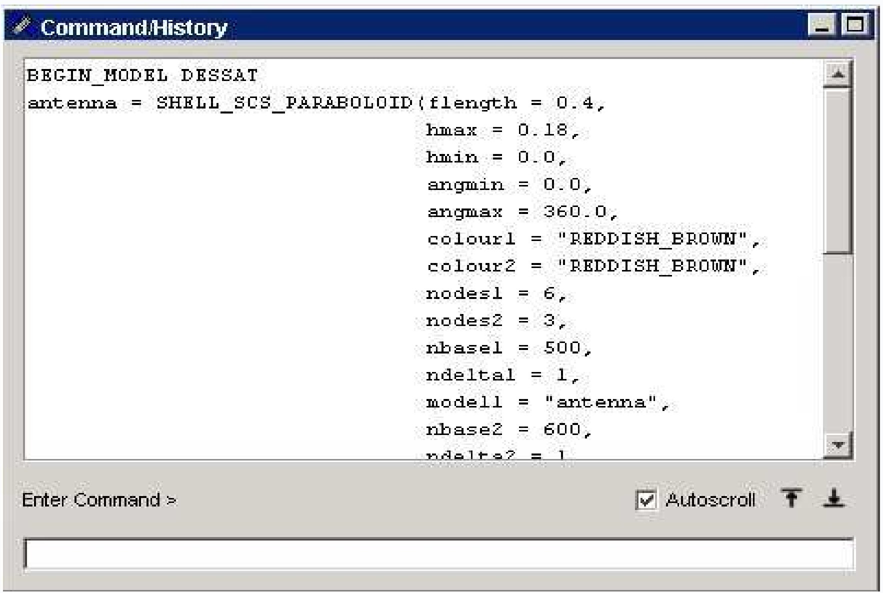
Tune tree window width



- New Icons -

GUI

ALSTOM

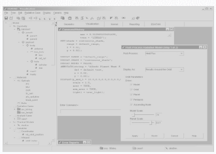


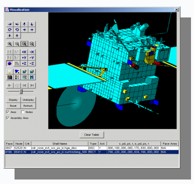
- Autoscroll Command -

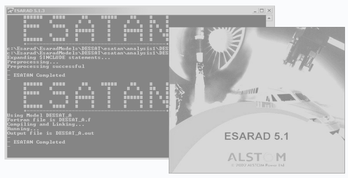
ESARAD v-5.1

ALSTOM

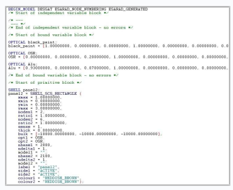
New features

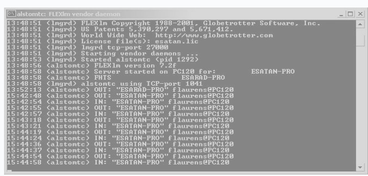






- GUI
- Visualisation
- ESATAN integration
- Text edit mode
- License mechanism





- Summary -

Visualisation

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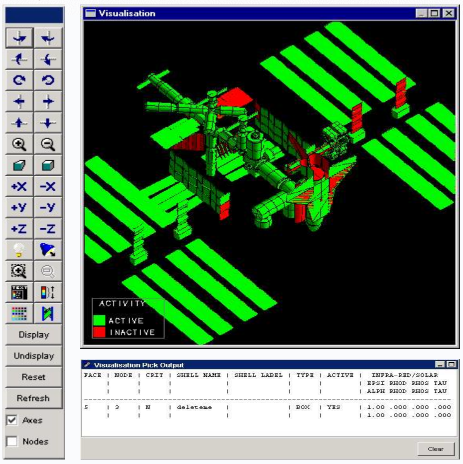
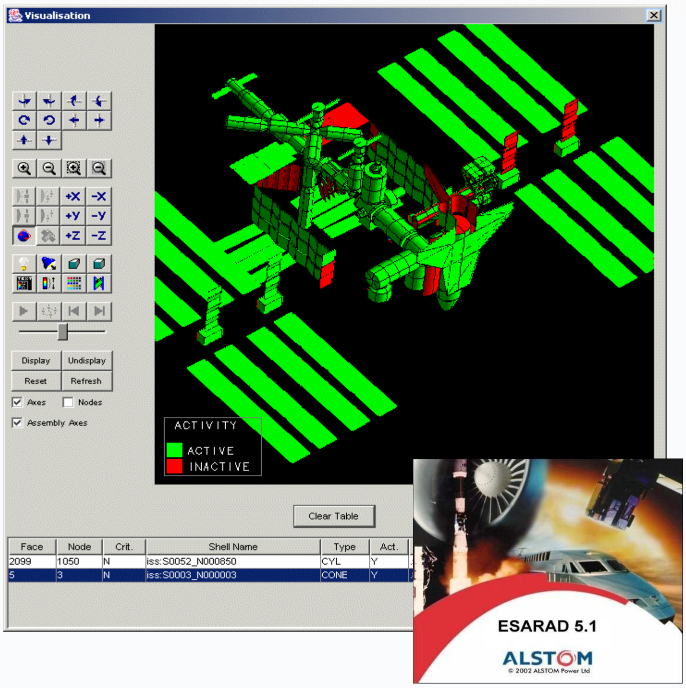


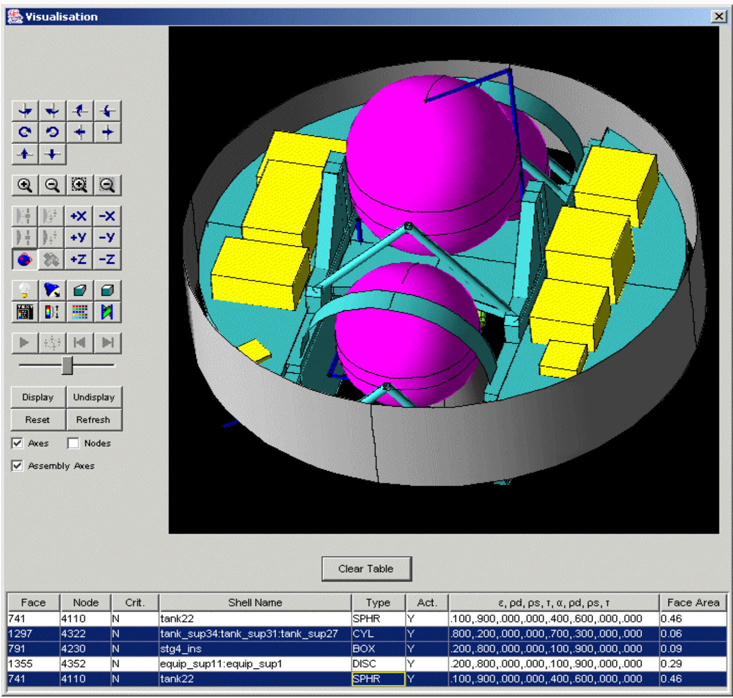


- New Layout -

Visualisation

ALSTOM

- Can be set always on top
- New views
  - Centred on model
  - Far from Sun/planet
- Animation mode



- Organisation -

Visualisation

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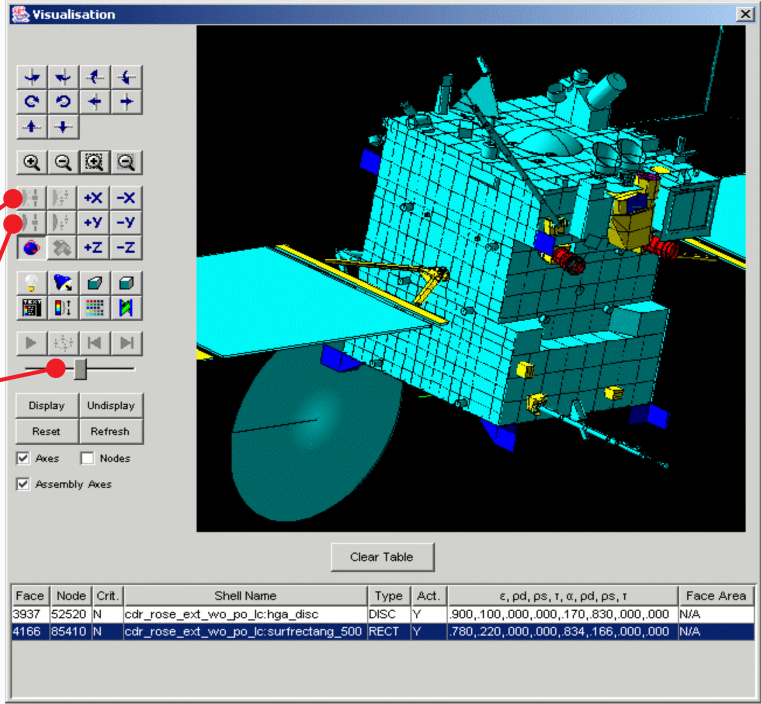
- Display options
  - Relative to Sun
  - Relative to planet
  - Animation

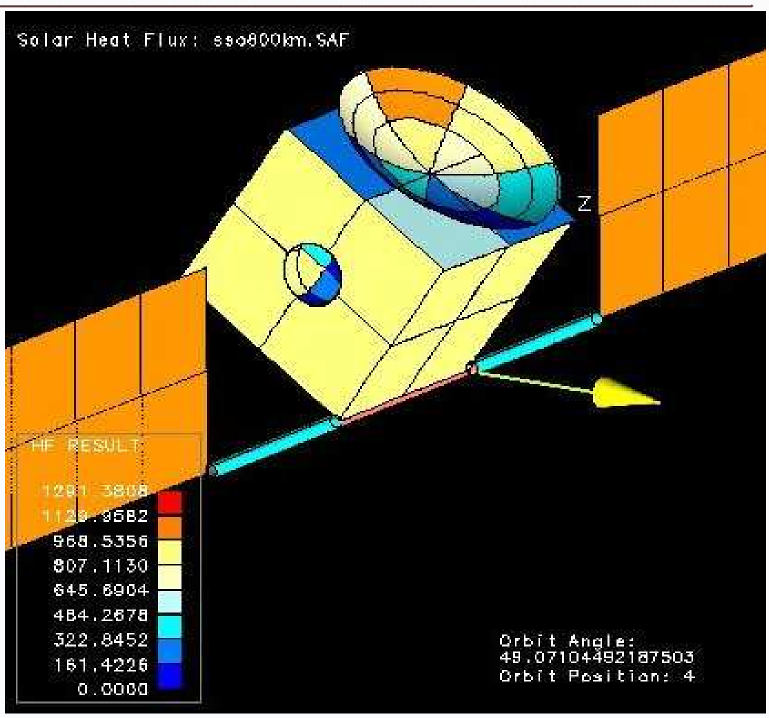


- New Options -

Visualisation

ALSTOM

- Pink axis
  - Indicates rotation axis
- Yellow arrow
  - Indicates pointing direction



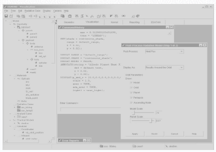
- Display of Assemblies -

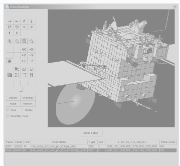
ESARAD v-5.1

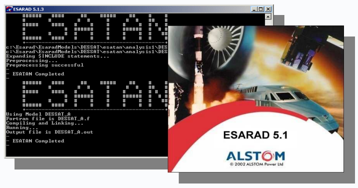
ALSTOM

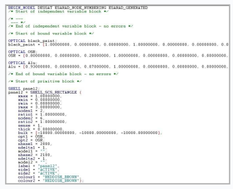
New features

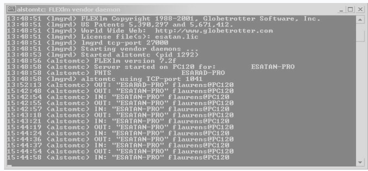
- GUI
- Visualisation
- ESATAN integration
- Text edit mode
- License mechanism











- Summary -

ESATAN Integration

ALSTOM

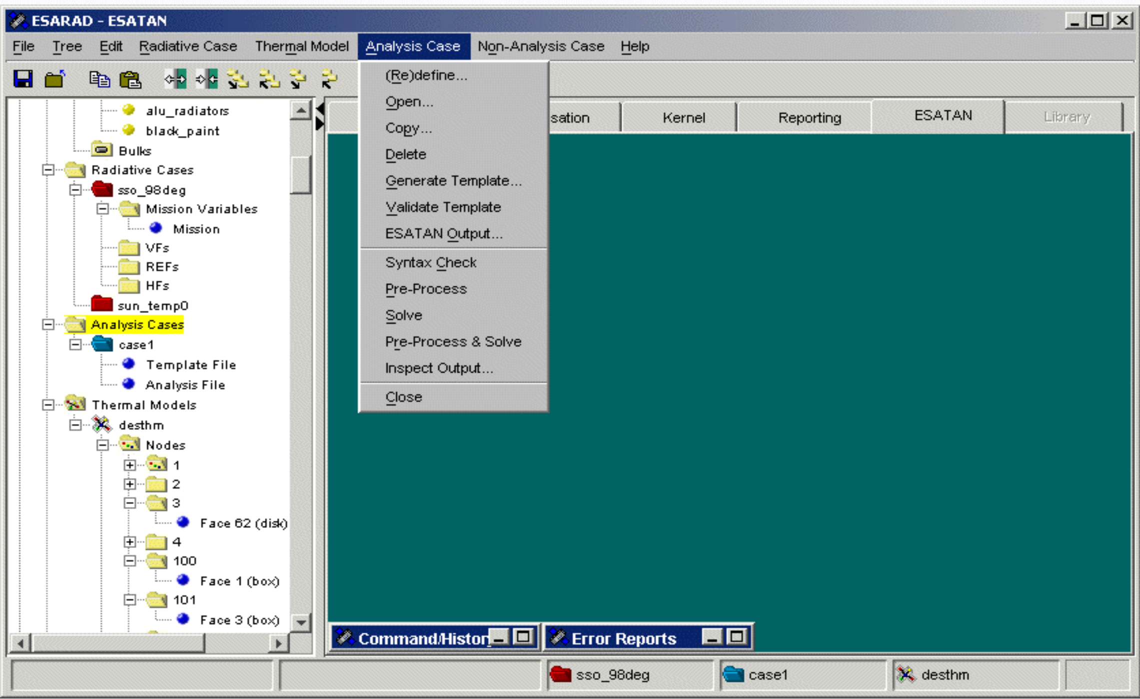
- Interactive built-in interface to transfer ESARAD results to ESATAN
- ESATAN can now be controlled directly from ESARAD

- Directory *esatan* created within model directory
  - Working directory
  - Need to reload all 4.3.2 models

- ESARAD / ESATAN Interface -

ESATAN Integration

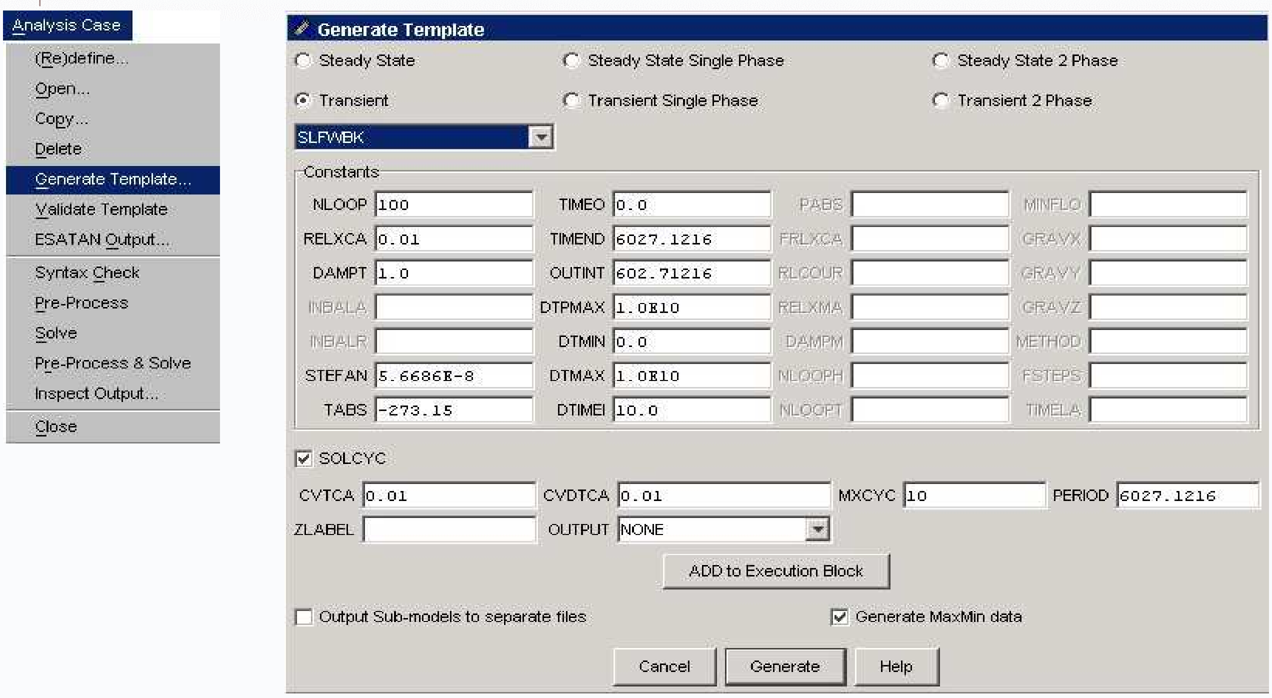
ALSTOM



- Analysis Case Menu -

ESATAN Integration

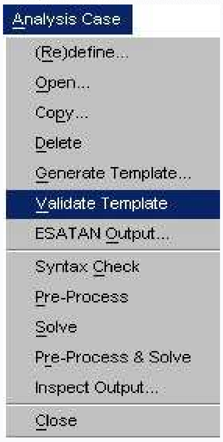
ALSTOM



- Generating Template Files -

ESATAN Integration

ALSTOM

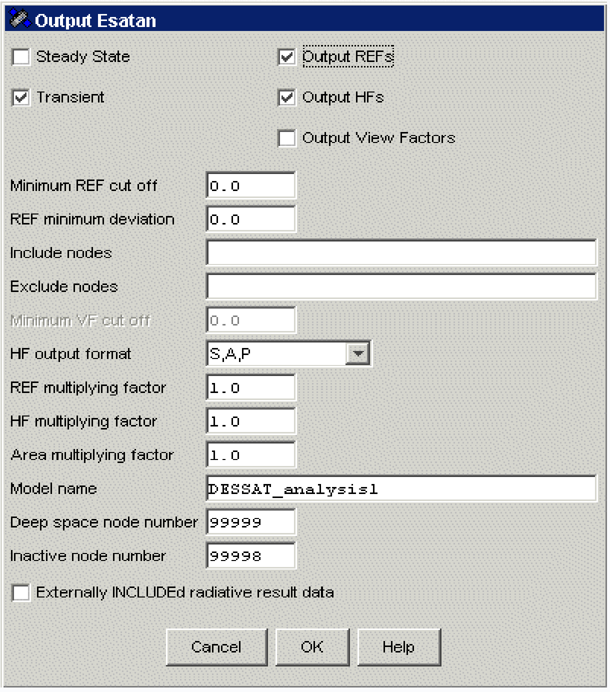



```
# template file: Template.tpl
# Esarad version 5.1.3, run date 15:27 Thu 29 Aug 2002
# Model name: DESSAT        Analysis case: analysis1
$MODEL DESSAT
  $LOCALS
  $NODES
  # GENCODE NODES - DO NOT REMOVE

  $CONDUCTORS
  # GENCODE CONDUCTORS - DO NOT REMOVE

  $CONSTANTS
  # GENCODE CONSTANTS - DO NOT REMOVE

  $ARRAYS
  # GENCODE ARRAYS - DO NOT REMOVE

  $SUBROUTINES
  # GENCODE SUBROUTINES - DO NOT REMOVE

  $INITIAL
  # GENCODE INITIAL - DO NOT REMOVE

  $VARIABLES1
        IF (SOLVER(:2) .EQ. 'SS') THEN
            CALL QAVERG
        ELSE
            CALL QCYCLC
            CALL RCYCLC
        END IF
  $VARIABLES2
  $EXECUTION
  # Steady State Solution
        RELXCA=0.001
        NLOOP=1000
        CALL SOLVIT
  # Transient Solution
        TIMEND=PERIOD
        DTIMEI=TIMEND/100.0
        OUTINT=TIMEND/10.0
        CALL SLFWBK
  $OUTPUTS
        CALL PRNDTB(' ','L,T,QS,QE,QA,C',CURRENT)
        CALL DMPGFF(' ',CURRENT)
$ENDMODEL # DESSAT
```

- Validating Template Files *.tpl -

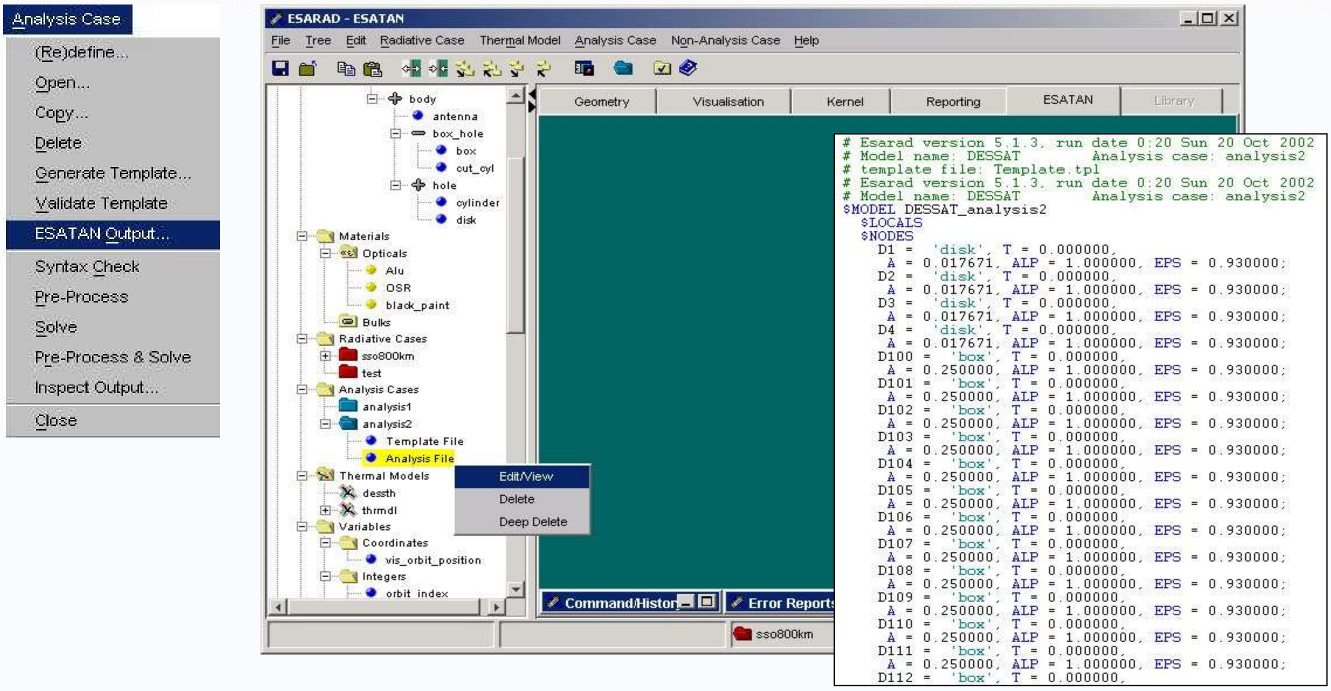
ESATAN Integration

ALSTOM



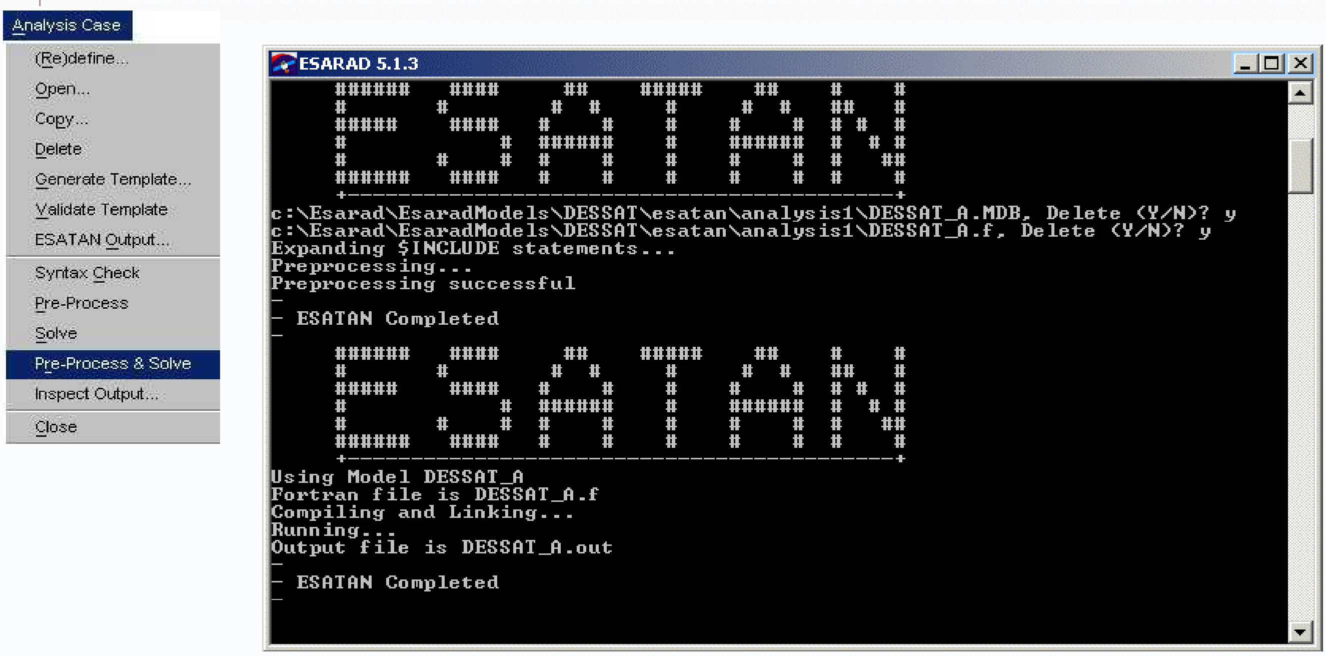
- ESATAN File Generation -

ESATAN Integration



- ESATAN File Generation -

ESATAN Integration



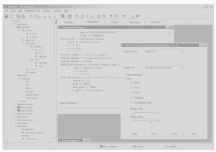
- ESATAN Run Control -

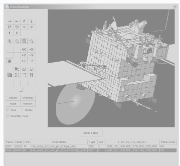
ESARAD v-5.1

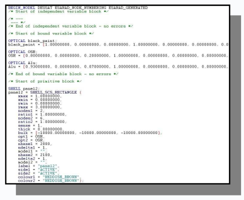
ALSTOM

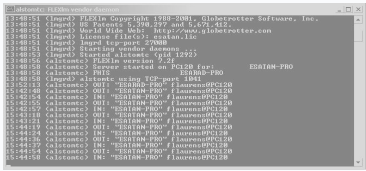
New features

- GUI
- Visualisation
- ESATAN integration
- Text edit mode
- License mechanism







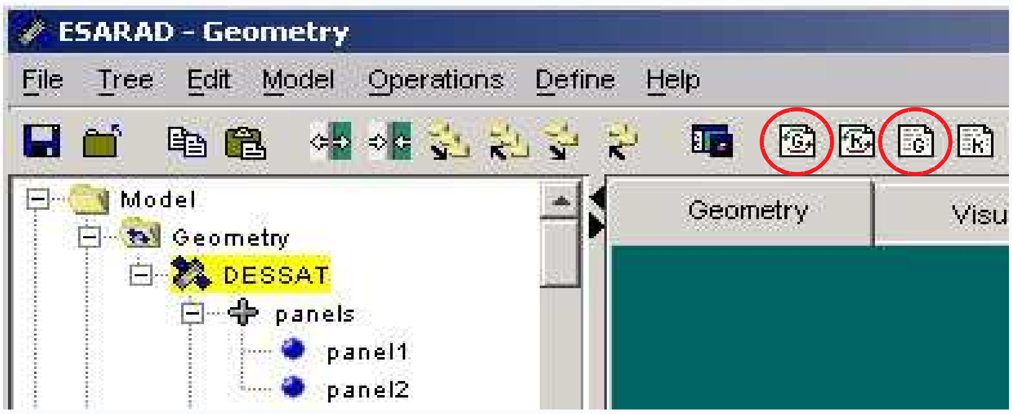


- Summary -

Text Edit Mode

ALSTOM

- Replaces the old ‘update model’ in v-3.2.7
- Allows the user to update the model in the geometry file and to reload it in the GUI via a simple click

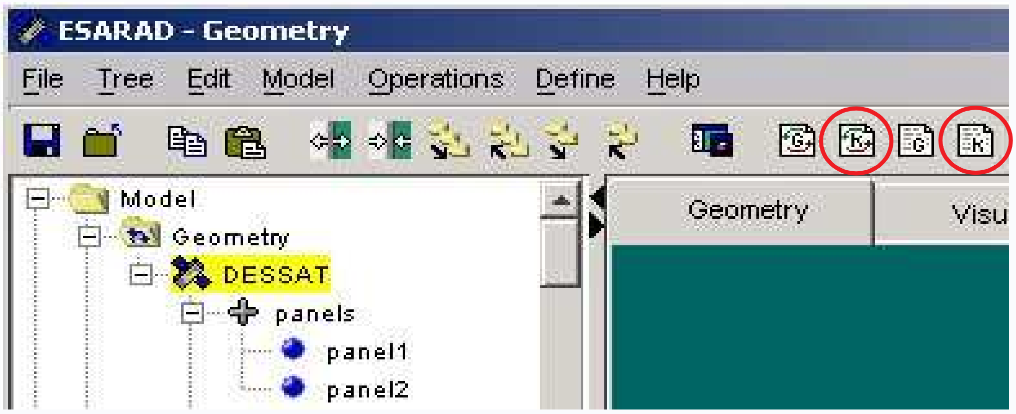


- Geometry -

Text Edit Mode

ALSTOM

- Allows the user to change the kernel file and to re-launch it in the GUI via a simple click

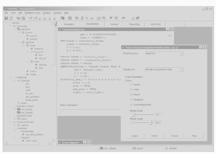


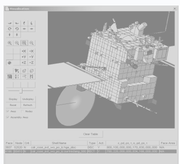
- Kernel -

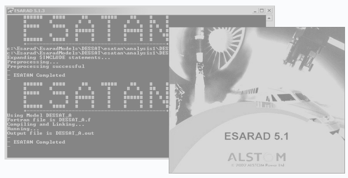
ESARAD v-5.1

ALSTOM

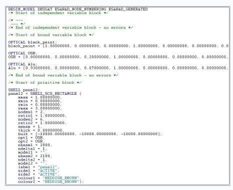
New features



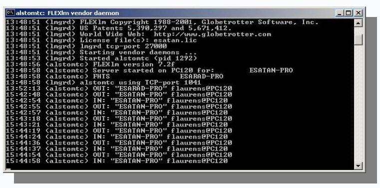




- GUI
- Visualisation
- ESATAN integration
- Text edit mode



- License mechanism

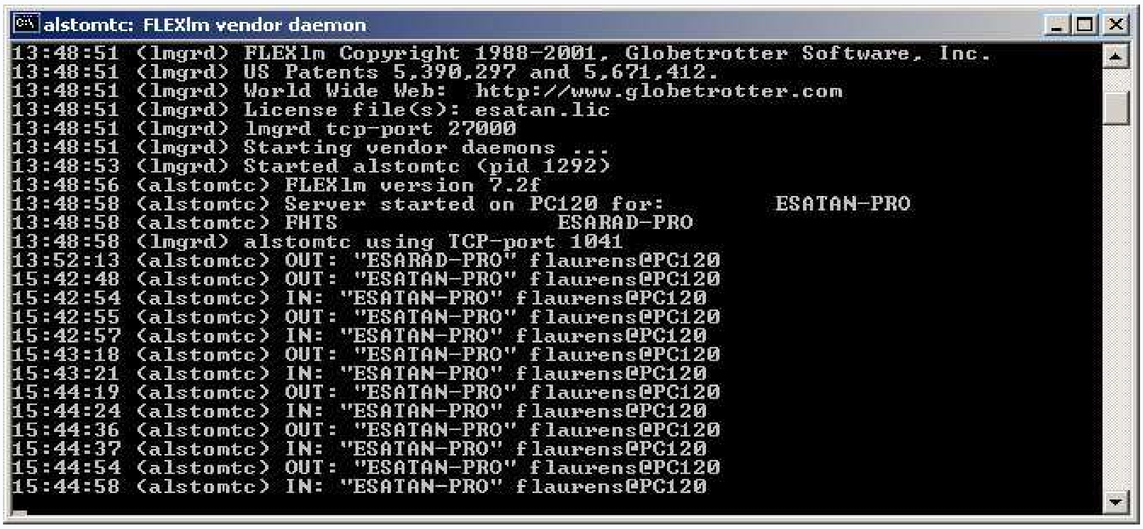


- Summary -

License Mechanism

ALSTOM

- Need to start the *lmgrd.bat* file prior to executing the application



License Mechanism

ALSTOM

- *lmgrd.bat* can be set up in the startup menu of Windows by creating a shortcut

License Mechanism

ALSTOM

Model Migration

- ESATAN v-8.7 migration period
  - Released in December 2001
  - Free FLEXlm keys were provided upon request to cover model migration until end of June 2002
- ESARAD v-5.1 released in June 2002
  - Migration period has started
  - Existing users can request free FLEXlm keys until end of April 2003

- Overlapping Period -

ESARAD v-5.1

ALSTOM

- New Features Summary -

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Appendix H: Application of EcosimPro to Bio-regenerative Life Support Components

Application of EcosimPro
to
Bio-regenerative Life Support Components

A. Rodriguez
ESTEC/TOS-MCT

Application of EcosimPro® to Bio-regenerative Life Support Components

Alexander Rodriguez, ATOS ORIGIN & Luis Ordonez Inda, ESA ESTEC / TOS-MCV

EcosimPro®

Is a software package for modeling and simulating dynamic systems, which could be represented by differential-algebraic equations and discrete events

Is developed and maintained by EA International, Spain with ESA support

Unique Features

•Easy interconnection of components by user- or pre-defined PORTS

•Non-causality of equations

a=f(b) ó b=g(a) a=b'+c" ó c"=a-b'

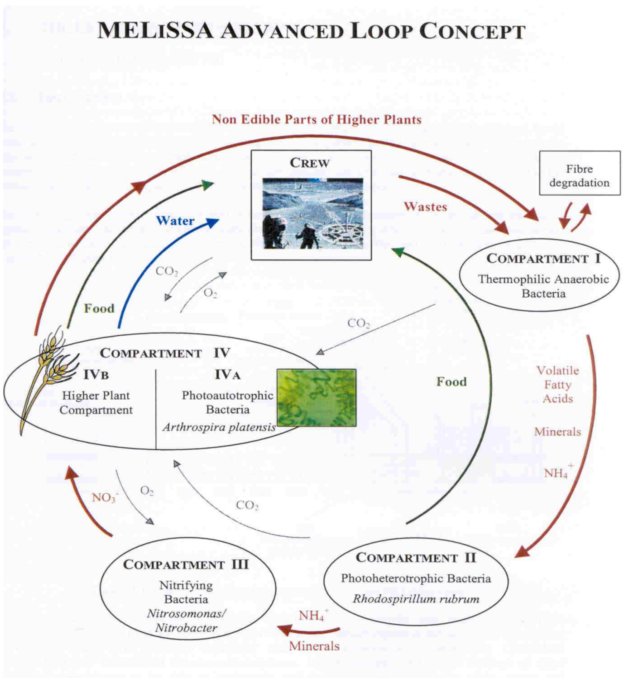
Bio-regenerative life support system (BLSS)

DEFINTION

BLSS is a system that is capable of recovery of edible biomass, water and oxygen from waste, carbon dioxide and minerals based on processes driven by biological entities.

•To date, a BLSS with a high degree of closure for all material flows does not exist

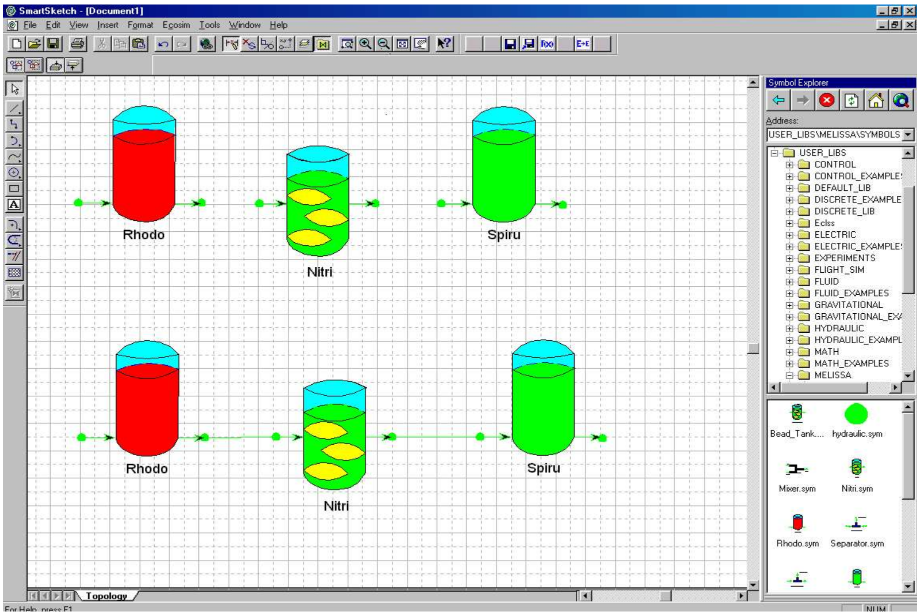
•MELiSSA has been conceived as a micro-organisms and higher plant based ecosystem intended as a tool to gain understanding of the behavior of artificial ecosystems, and for development of the technology for a future bio-regenerative life support system



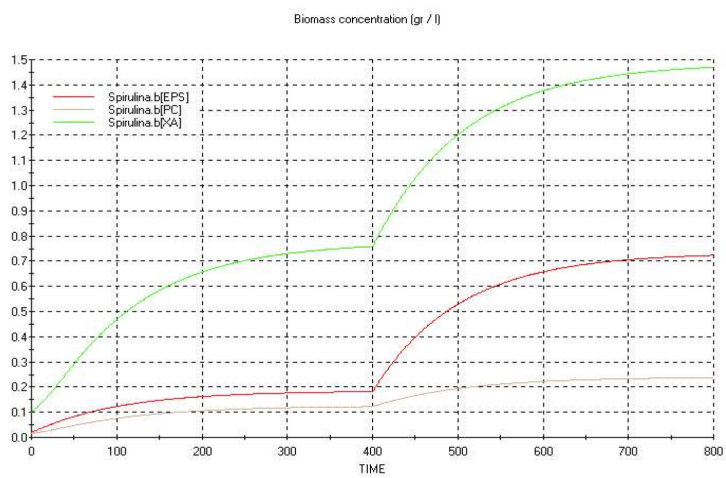
Simulations so far have been concentrated on compartment II, compartment III and compartment IVa

Simulations have been run as continuous and batch cultures using EcosimPro® and Matlab® /Simulink®

Screenshot of EcosimPro® Pre-processing Tool Smartsketch ®



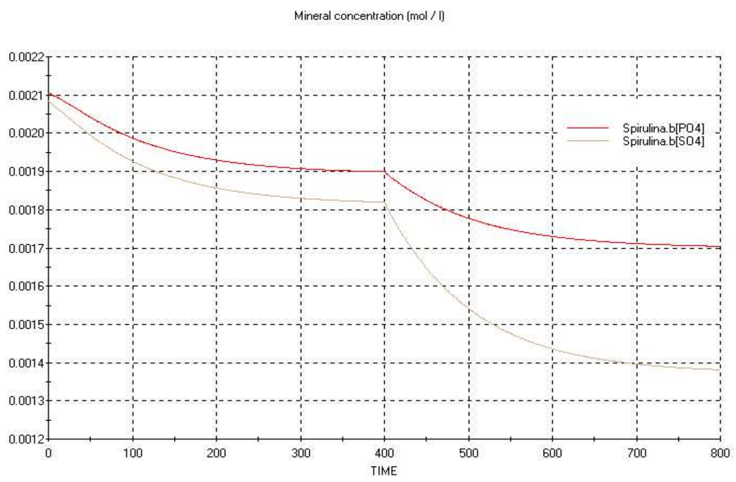
Simulation Results for a Photoautotrophic Compartment (1)



- proper concentration evolution of multiple compounds
- capability of handling step changes in the light flux satisfactorily
- Graph automatically generated using an included post-processing tool

ESTEC

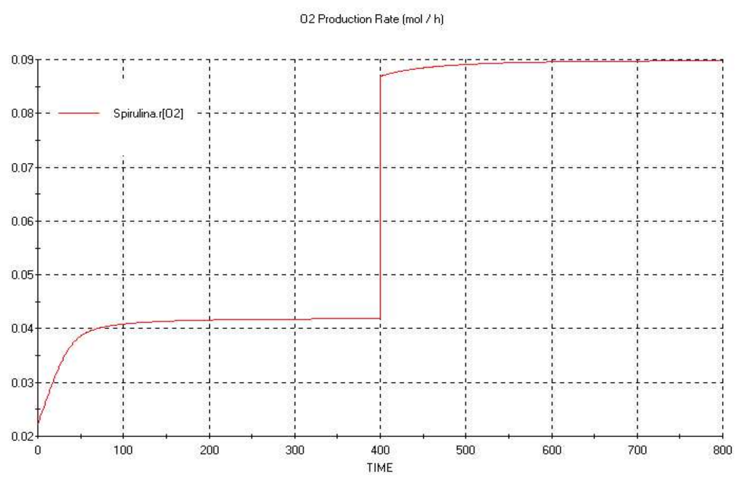
Simulation Results for a Photoautotrophic Compartment (2)



- proper concentration evolution of multiple compounds
- capability of handling step changes in the light flux satisfactorily
- graph automatically generated using an included post-processing tool

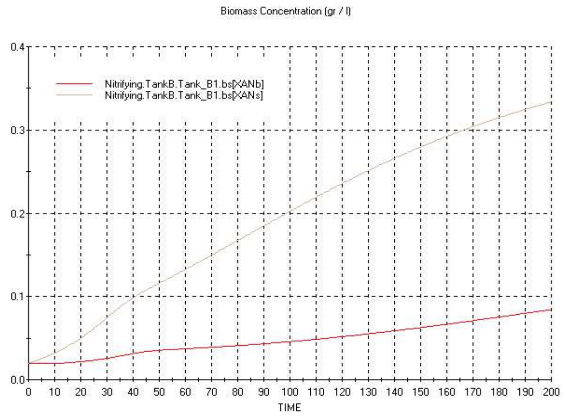
ESTEC

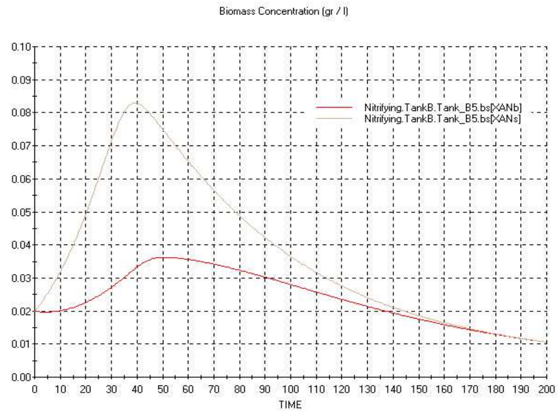
Simulation Results for a Photoautotrophic Compartment (3)



- proper rate evolution even at step changes
- capability of handling step changes satisfactorily

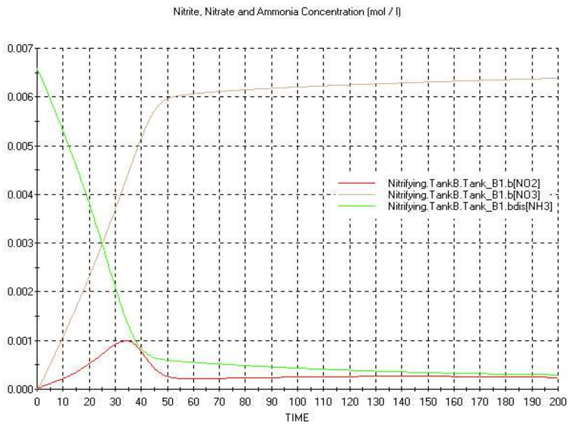
Simulation Results for a Nitrifying Compartment (1)

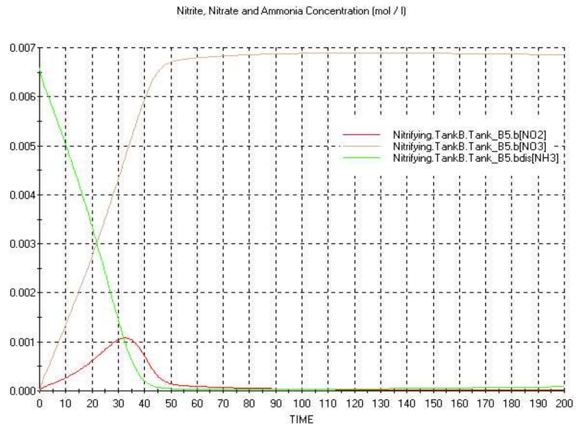




proper spatial and time resolution of concentrations of two kinds of biomass

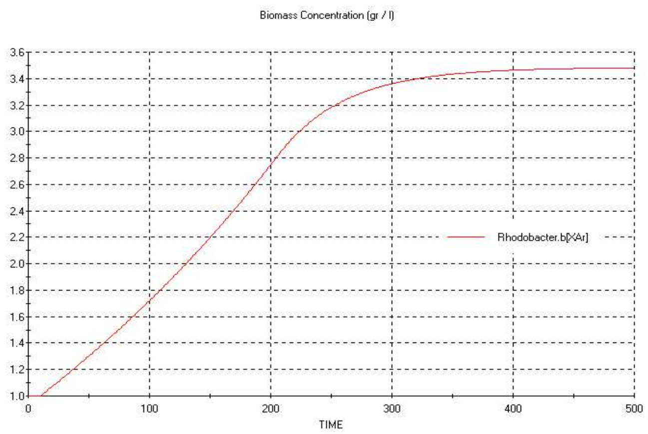
Simulation Results for a Nitrifying Compartment (2)





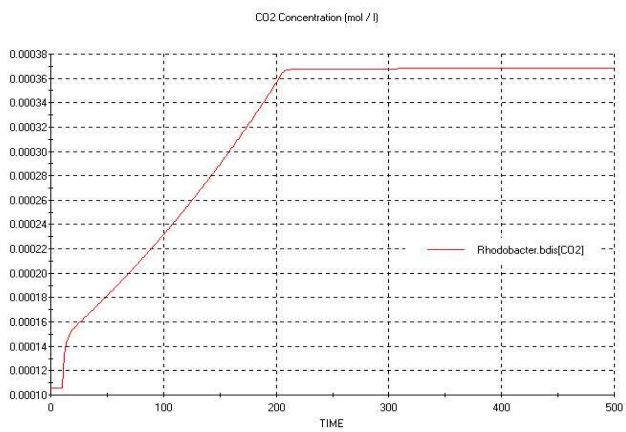
proper spatial and time resolution of concentrations of nitrogen containing compounds

Simulation Results for a Photoheterotrophic Compartment (1)



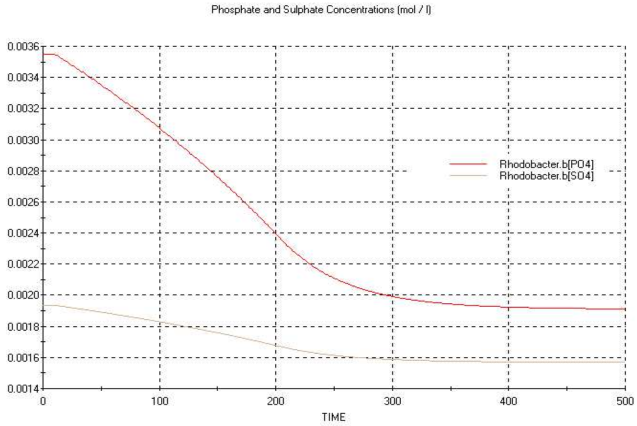
- proper concentration evolution of multiple compounds
- capability of calculating an initial steady state and start a subsequent transient analysis

Simulation Results for a Photoheterotrophic Compartment (2)



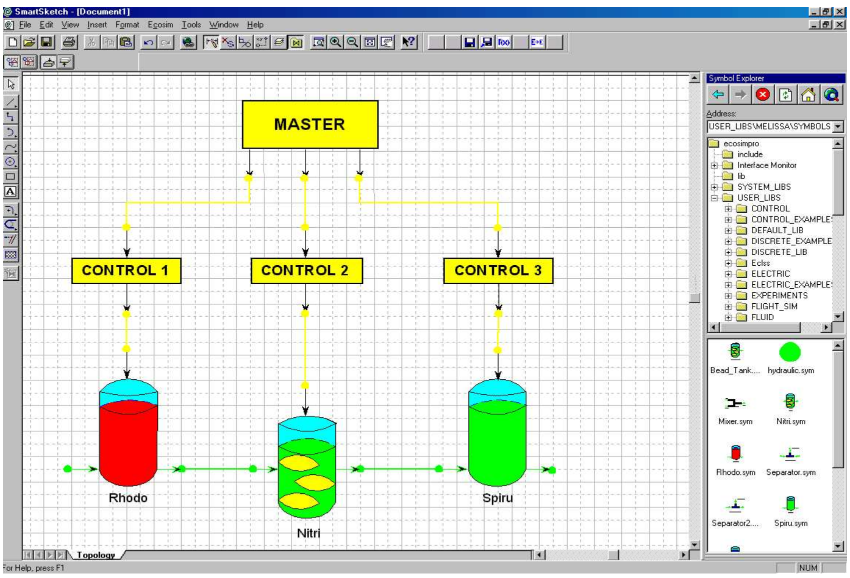
- proper concentration evolution of multiple compounds
- capability of calculating an initial steady state and start a subsequent transient analysis

Simulation Results for a Photoheterotrophic Compartment (3)



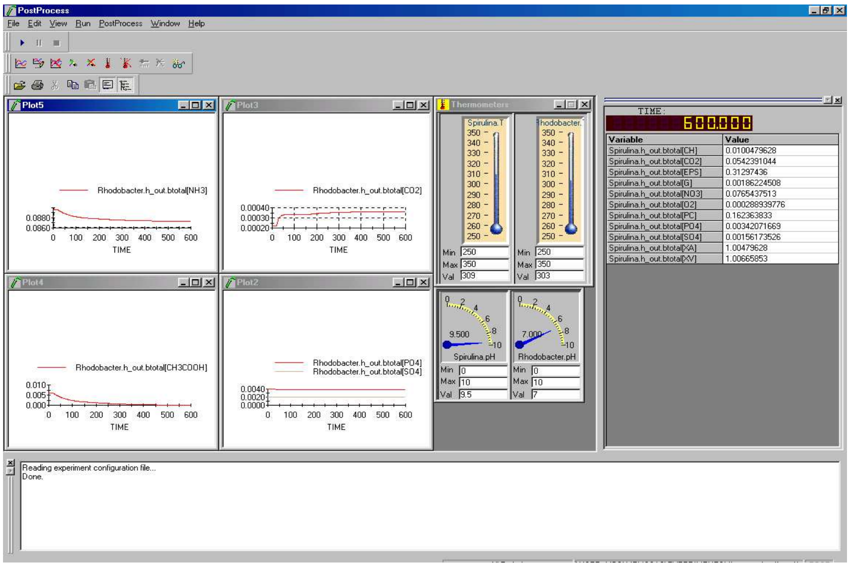
- proper concentration evolution of multiple compounds
- capability of calculating an initial steady state and start a subsequent transient analysis

Screenshot of EcosimPro® Preprocessig Tool Smartsketch ®



- 2level control structure implementation
- each component automatically generates c++code during compilation

Screenshot of EcosimPro® Postprocessig Tool EcoMonitor®



•results can be displayed in suitable form during and after simulation

•dynamic variables can be changed during simulation using the EcoMonitor®

Conclusion (1)

EcosimPro®

•Is capable of simulating components of bio-regenerative life support system components

•Could predict accurately the steady state and transient behavior of bio-regenerative elements

•Performs reasonably efficient and accurate

- •no thorough comparison to other suitable tools has been made yet
- •DDASSL solver has been chosen after Trade-off analysis by EA International

Conclusion (2)

EcosimPro®

•Object oriented capabilities allow simulation of single components or entire systems

•Object oriented capabilities allow simulation of control strategies in different layers

•Easy-to-use pre & post processing tools are included

•C++ code could be exported to run stand alone applications

•External C++ code could be implemented fairly easily in EcosimPro® components

Appendix I: ESATAN v8.7 & 8.8

ESATAN
v8.7 & 8.8

F. du Laurens d'Oiselay
Alstom

October 2002

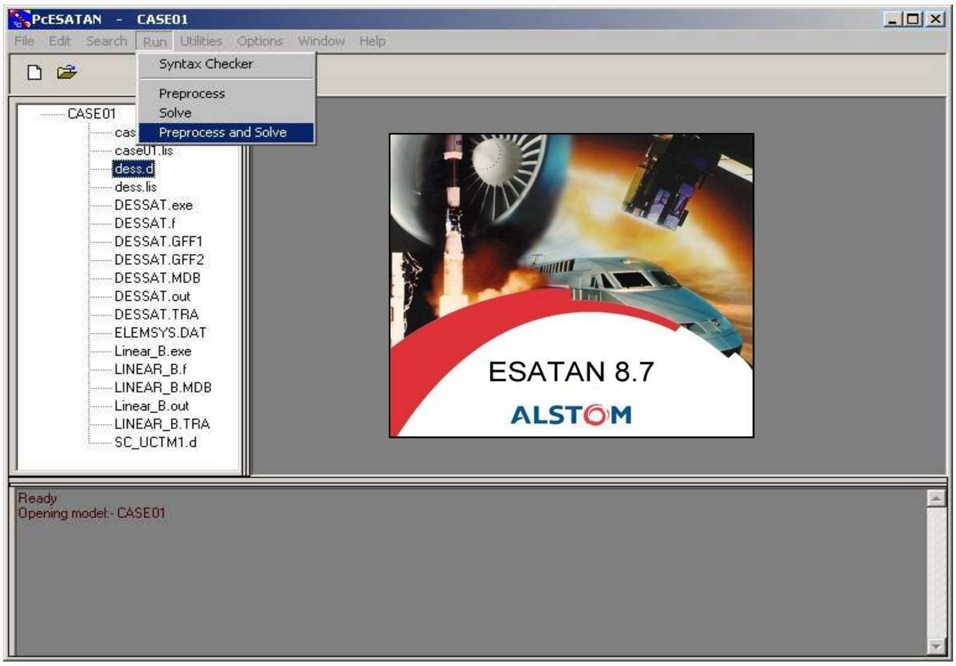
ESATAN v8.7 & 8.8

Julian Thomas
Frédéric du Laurens d'Oiselay

ALSTOM

ESATAN v-8.7

ALSTOM



- State in the Field -

ESATAN v-8.7

- ESATAN v-8.7
  - Released in December 2001
  - Free FLEXlm keys were provided upon request to cover model migration until end of June 2002
- Model migration now officially over
  - Old authorisation files obsolete
  - FLEXlm keys in full operation

- State in the Field -

ESATAN v-8.7

- Apostrophe sign [′] in comments
  - Not allowed in this version
  - Patch available upon request
- To comment the **`$INCLUDE`**
  - `#  $INCLUDE` and not `#$INCLUDE`
- External subroutine
  - Subroutine in **`$EXTERNAL`** model not recognised
- Beware of reserved names in ESATAN
- Missing substitution data in predefined elements not tested
- All these issues will be fixed in next version...

- Known Issues -

ESATAN v8.8 - Scope

ALSTOM

- Pre-Processor Improvements
- Fast Solvers
- Heat balance convergence
- Neutral output format (csv) for any data
- User constants defined any user “Mortran”
- Model name functions
- Node number functions (internal<->external)
- User documentation
- DTMAX treatment

- Continuing Commitment to Development -

ESATAN v8.8 - Scope

ALSTOM

- Pre-Processor Improvements
- Fast Solvers
- Heat balance convergence
- Neutral output format (csv) for any data
- User constants defined any user “Mortran”
- Model name function
- Node number functions (internal<->external)
- User documentation
- DTMAX treatment

- Continuing Commitment to Development -

SOLVFM Developments

ALSTOM

Fast, Scaleable Steady-State Solution

- Improved band-width optimisation
- Proprietary algorithm development
- ‘Detached node’ support
- Improved energy balance (c.f. SOLVIT)
- Near linear scalability
- Examples from test suite:
  - 30,000 nodes/50,000 GLs/150,000 GRs - 7sec
  - 3,000 nodes/6,000 GLs/800,000 GRs - 24sec

- SOLVFM Recommended Steady-State Solver -

SLFWBK Developments

ALSTOM

Transient

- Unique “Rate of change” based dynamic time-stepping optimisation
- Arithmetic node optimisation
- Consistency of temperature dependant data
- Prototype up to 25 times faster for some models

- Class Leading Transient Solution -

ESATAN v8.8 - Scope

- Pre-Processor Improvements
- Fast Solvers
- Heat balance convergence
- Neutral output format (csv) for any data
- User constants defined any user "Mortran"
- Model name function
- Node number functions (internal<->external)
- User documentation
- DTMAX treatment

- Continuing Commitment to Development -

Heat Balance Convergence

- Extension of heat balance control constants to thermal steady-state routines
  - INBALA (absolute energy balance) vs ENBALA
  - INBALR (relative energy balance) vs ENBALR
- Supported in both SOLVIT and SOLVFM

- Increased Analysis Control -

ESATAN v8.8 - Scope

- Pre-Processor Improvements
- Fast Solvers
- Heat balance convergence
- Neutral output format (csv) for any data
- User constants defined any user “Mortran”
- Model name function
- Node number functions (internal<->external)
- User documentation
- DTMAX treatment

- Continuing Commitment to Development -

“CSV” Output

CSV = Comma Separated Value

- New library function for outputting to Comma Separated Value

```
PRNCSV(ZLABEL,ZENTS,CNAME,OUTFOR,FILECS);
```

  - ZLABEL, ZENTS and CNAME have normal meaning
  - OUTFOR defines grouping by node or data type
  - FILECS defines output stream number

- Plotting, Archiving, Database Import, etc. -

ESATAN v8.8 - Scope

- Pre-Processor Improvements
- Fast Solvers
- Heat balance convergence
- Neutral output format (csv) for any data.
- User constants defined any user “Mortran”.
- Model name function
- Node number functions (internal<->external)
- User documentation
- DTMAX treatment

- Continuing Commitment to Development -

Model & Node Functions

- SUBMOD() - return name of current model
- SUBMDN(*nodei*) - return name of model containing internal node reference *nodei*
- NODNUM(*nodei*) - return user node number of internal node number *nodei*
- *?*INTNOD(*cname, nodei*) - return internal node number of user node *nodei* in model *cname*

- Increased Modelling Flexibility -

ESATAN v8.8 Summary

- Fast solution in both steady-state and transient
- Heat balance convergence
- New neutral output (csv) routine
- User constants defined by other constants, etc.
- Model & Node number function

- Available Soon -

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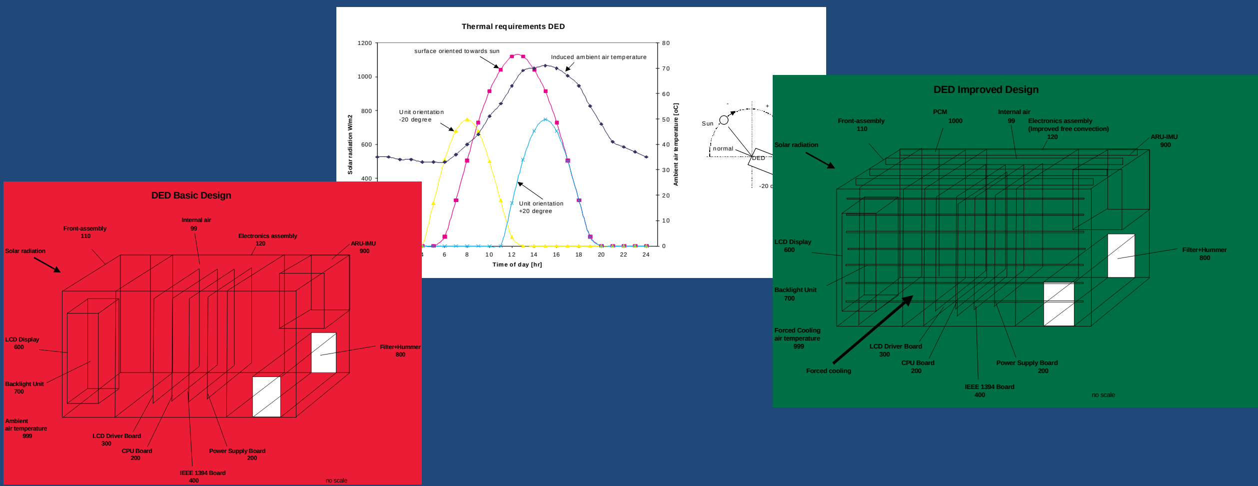
Appendix J: Integrated thermal design and the thermal numerical tool box

Integrated thermal design
and the
thermal numerical tool box

J. van Es
NLR

Integrated thermal design and the thermal numerical toolbox



R. C. van Benthem, A.W.G. de Vries and J. van Es, Thermal Control Group Space Division

Contents

- **Introduction**
- **ESATAN as thermal modelling tool in integrated design**
  - Thermal design of a cockpit control panel in hot conditions.
  - Thermal design of the pre-launch isolation of the BIOFILTER experiment.
- **Requirements for thermal S/W-tools in thermal design.**
- **Conclusions and recommendations.**

Introduction

Integrated thermal design in small thermal designs

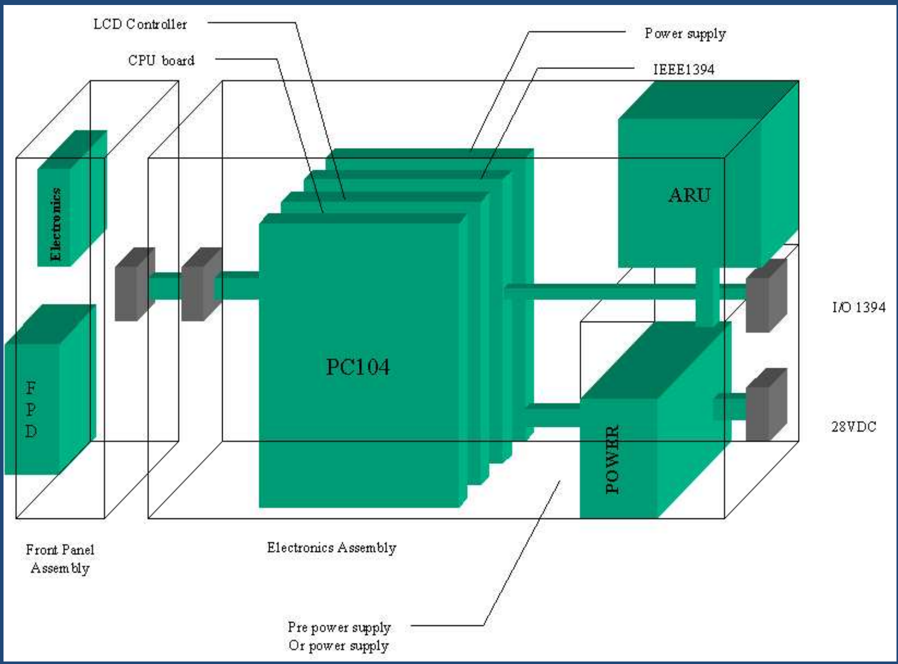
- **More and more thermal design is started in early phases of design (concurrent design) to:**
  – Minimise mass of thermal control subsystem
  – Avoid re-design at the end of a project
  – Maximise integration of structural and thermal design
  – Reduce development time and costs

Introduction

Thermal S/W packages are useful tools in early trade-offs to:

- **Perform transient analysis**
- **Determine impact of orbital changes**
- **Compare design options**
- **Perform sensitivity analyses**

Thermal design of a cockpit control panel in desert conditions

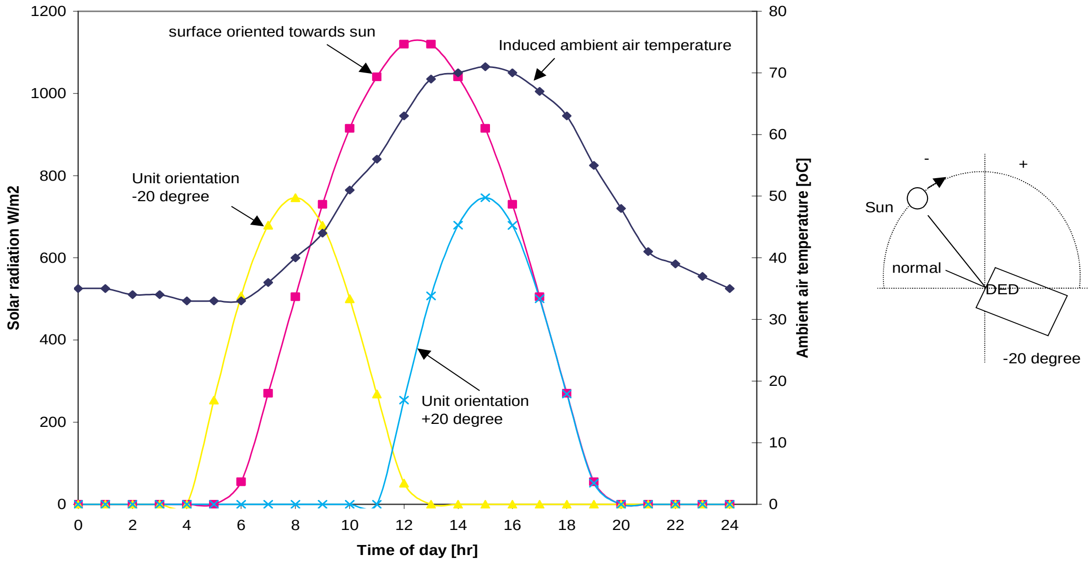


Thermal design of a cockpit control panel in hot conditions

- **Problem to solve:**
  - A basic thermal design for a cockpit panel display does not meet the temperature requirement of 85 °C during:
    - non-operational conditions in hot conditions
    - start-up in hot conditions
- **Conditions**
  - Solar radiation 1120 W/m^2 at maximum.
  - Ambient air 71 °C.
  - An adiabatic interface with instrument panel is required.
  - Cooling air 35 °C

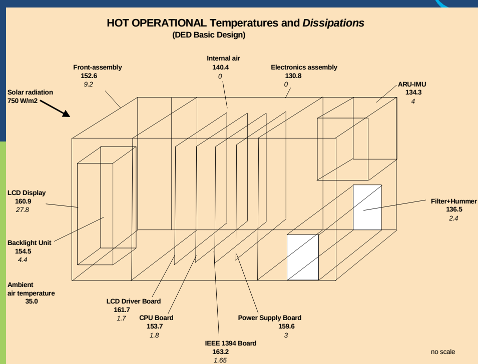
Thermal design of a cockpit control panel in hot conditions

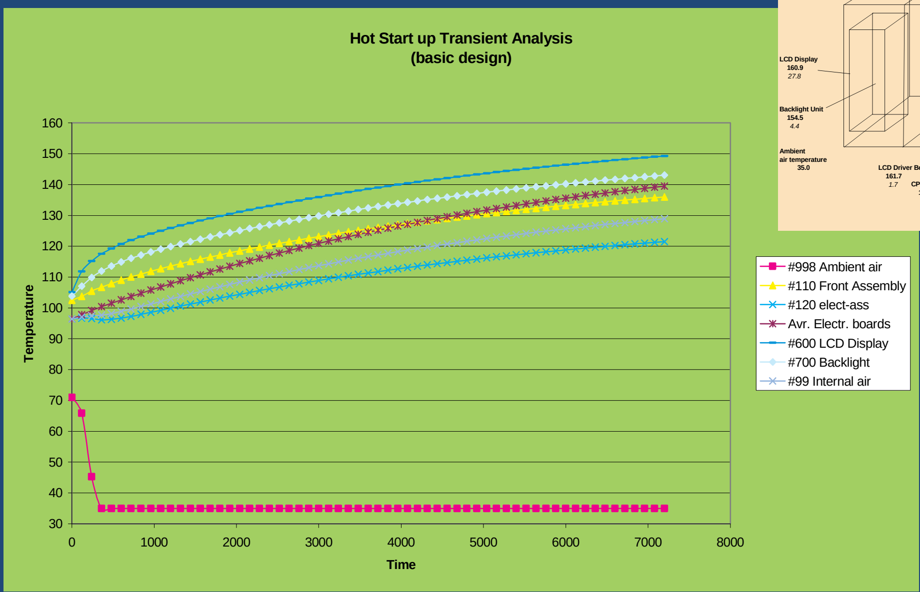
Ambient Conditions



Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Thermal design of a cockpit control panel in hot conditions

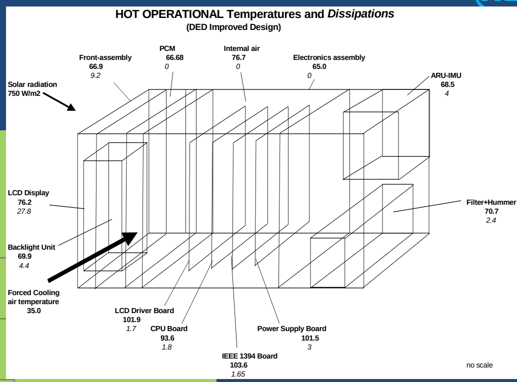


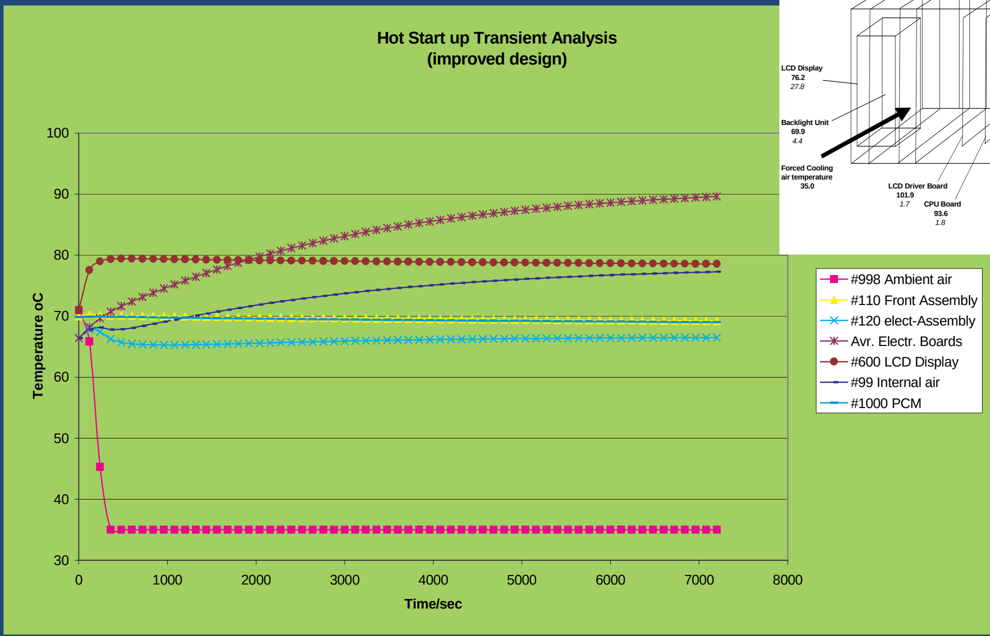


Basic Design

- Free convection
- No thermal H/W

Thermal design of a cockpit control panel in hot conditions





Improved Design

- Forced convection
- PCM

Thermal design of a cockpit control panel in hot conditions

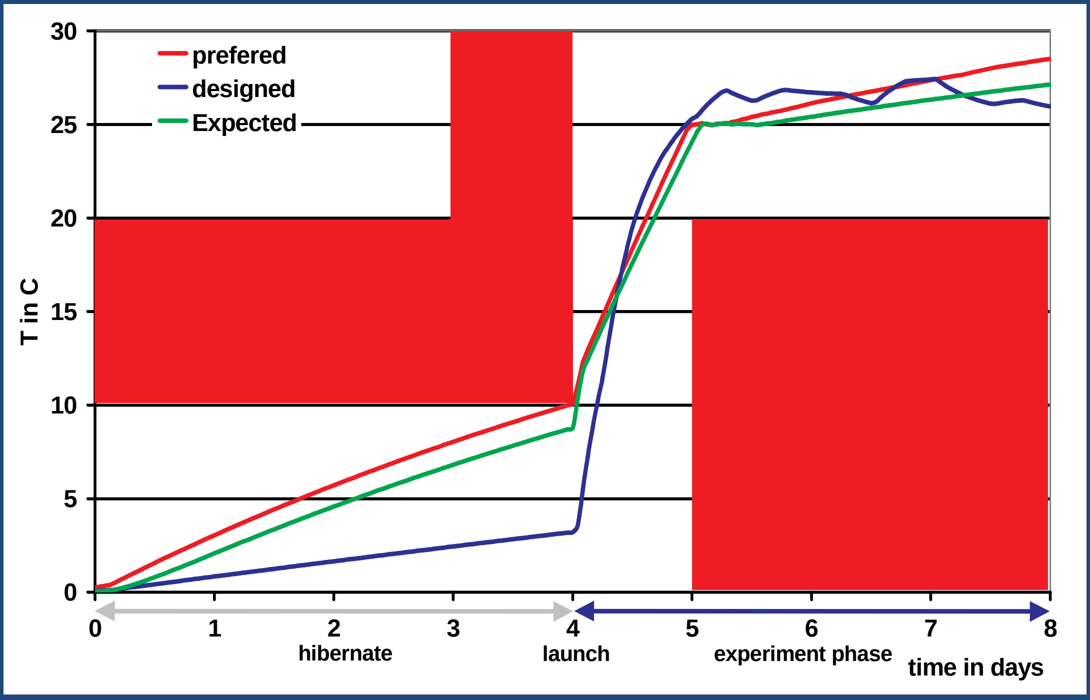
- **Transient thermal modelling was needed and convinced the customer to change design.**
- **PCM is easy implemented in ESATAN, however:**
  - It is not (yet) a standard feature.
  - Error messages are unclear.
  - ESATAN provides no support for structured set-up of in-house ESATAN-code.

Thermal design of the pre-launch isolation of the BIOFILTER experiment

- **A high-insulating experiment container was required to keep a biological bacterial growth experiment below 10 °C for 4.5 days without active cooling.**

- **Conditions**
  - Ambient temperature 22 °C.
  - Limited volume.
  - Limited power budget (no active cooling).
  - Overall thermal conductivity less than 0.1 mW/m*K is required.

Thermal design of the pre-launch isolation of the BIOFILTER experiment

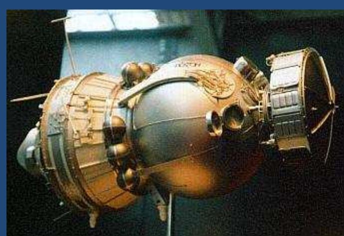


Thermal design of the pre-launch isolation of the BIOFILTER experiment

- **Design**
  - A high insulating container is manufactured with high vacuum and MLI.
  - PCM is added as heat capacity and latent heat.
  - A heater is implemented to heat the experiment
- **Results**
  - Design ready in 6 months after start thermal design.
  - Overall conductivity is 0.4 mW/mK (0.2 W/m*K required)
  - 150 g PCM (5.9 °C) is enough to satisfy the temp. requirements.
  - Heater power is sufficient to heat the experiment to 25 °C.

Thermal design of the pre-launch isolation of the BIOFILTER experiment

- **Transient thermal modelling was used to calculate design performance and to support design trades.**
- **MLI performance is strongly dependent on vacuum**
  - Test were needed to confirm feasibility.
- **The modelling was performed by a new ESATAN user**
  - ESATAN showed to be easy to learn but error messages were unclear.
  - Effort was unfortunately for nothing.



Requirements to the thermal numerical toolbox for integrated design

- **Easy user interface with short learning curve.**
- **Large toolbox with material properties.**
- **Easy interfaces with ESARAD/RADCAD/STK etc.**
- **Toolbox with (with a small number of nodes) thermal design options such as:**
  - Phase change materials
  - Honeycomb material
  - MLI (in vacuum)
  - Heat pipes (LHP, CPL)
- **Possibility of easy implementation of new design options.**

Conclusion & recommendations

- **The ESA thermal numerical toolbox is a useful tool in integrated (thermal) design, to support design trade-offs for:**
  - **transient thermal modelling**
  - **impact of orbital changes**
- **Most capabilities are present in current ESATAN however**:
  - **The user interface can be more structured.**
  - **The error messaging is often unclear.**
  - **The program invites the user to program him/herself. Also here a structure could provide faster modelling.**

Conclusion & recommendations

- **Statement:**
  The added value of small thermal models in the early phase of a project is orders larger than the added value of large thermal models in later stages of a project.

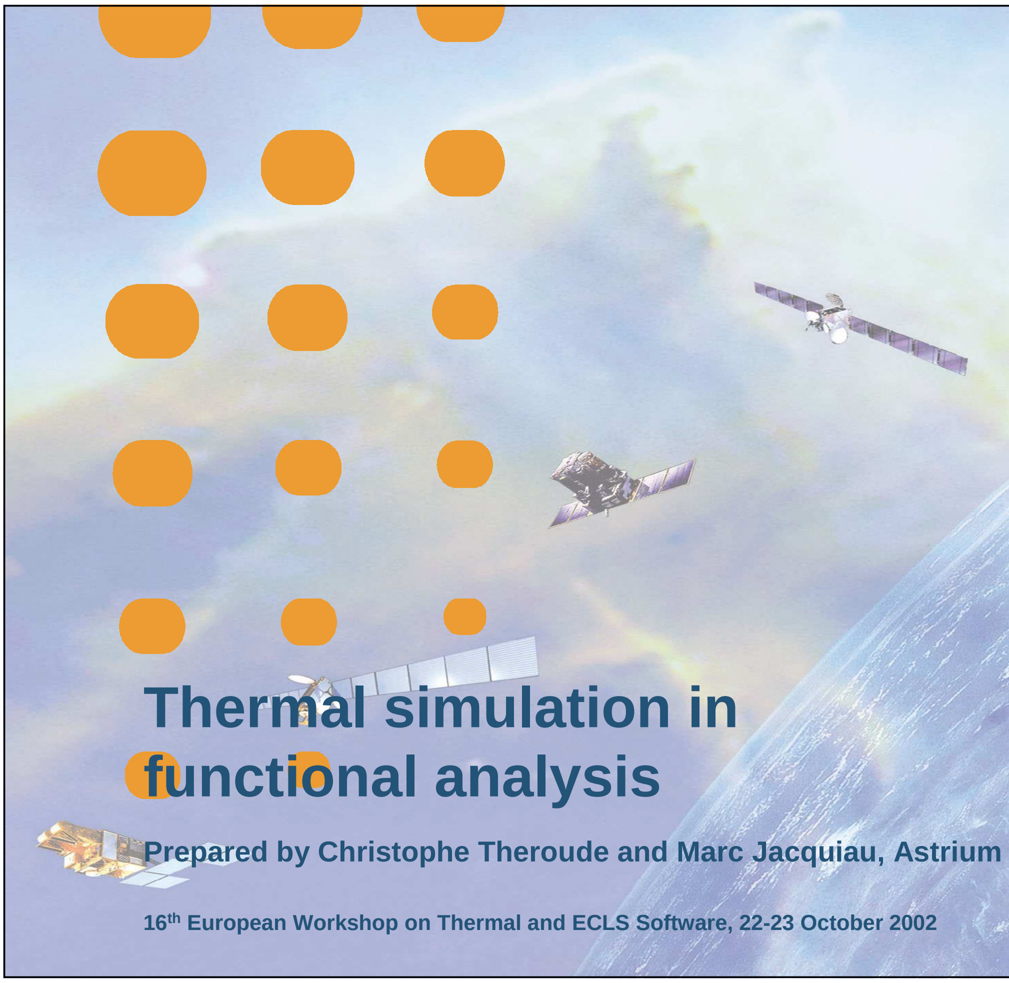
- **Therefore:**
  R&D of thermal S/W tools should be focussed on development of tools and data exchange to support thermal trade-offs.

- **Open source S/W is certainly a possibility to increase the improve the functionality and efficiency of the current S/W-tools.**

Appendix K: Thermal simulation in functional analysis

Thermal simulation
in
functional analysis

M. Jacquiau
Astrium SAS



Thermal simulation in functional analysis

Prepared by Christophe Theroude and Marc Jacquiau, Astrium SAS

16th European Workshop on Thermal and ECLS Software, 22-23 October 2002

Introduction

- **Besides the classical geometrical approaches used to model the thermal behaviour of spacecraft, there is also a need to perform simpler analysis :**
  - →Development of a tool adapted to perform preliminary thermal design
- **Moreover, a geometrical approach doesn't fit the modelling needs for sub-system performances analysis like Power, Propulsion, etc. :**
  - →Development of *functional* tools to perform Power and Propulsion analysis
- **The chosen approach is to describe the problem with a set of differential equations that are solved by a numerical solver**
  - The model can be coupled with a geometrical simulation to compute flux, radiative coupling, etc

Software concepts

- **These software are organised under the same basis :**
- **They are based on an common toolkit aimed to describe and solve the problems that can be modelled with a network of equations**
- **Each component of the network is described by a mathematical model of its behaviour**
- **The model can support different types of node : thermal, fluid, control, electric**
- **Each tool is integrated in a same graphical interface :**
  - Schematic editor
  - Visualisation tool (text editor, 2D plot visualisation)
  - Post-processing : interface with Excel

Tools description

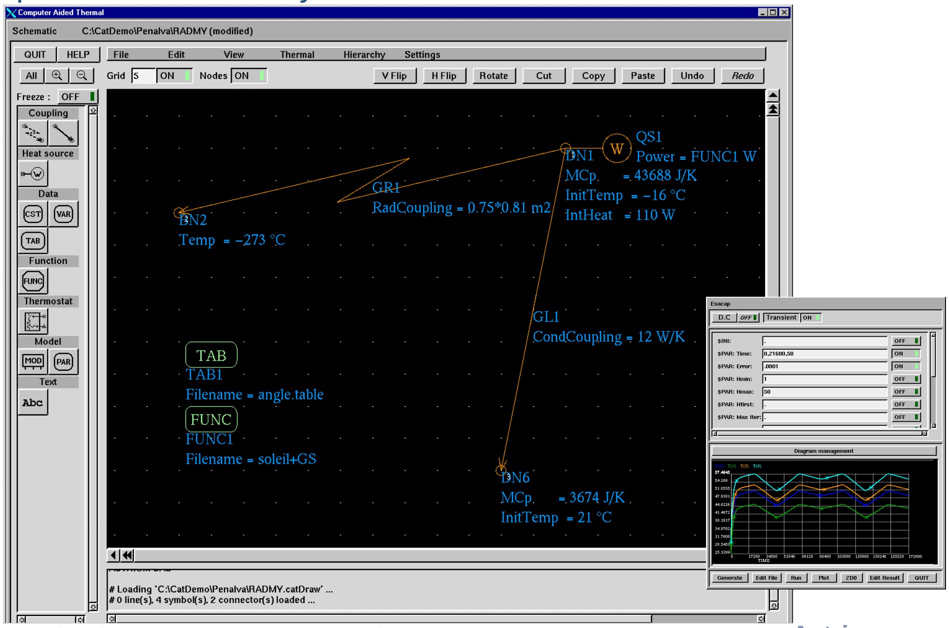
- **CAT**

  Conception d'Architecture Thermique in French
  - For thermal pre-dimensioning adapted for small models
  - Easy to use and easy to understand
- **CAP**

  Computer Aided Propulsion
  - For quick design of propulsion systems
  - Detailed performances analysis of propulsion systems
  - Exploitation of in-orbit data
  - Ventilation and venting analysis
- **POWER**
  - For quick design of power systems
  - Detailed performances analysis of power systems

CAT

- **CAT : a software tool for thermal preliminary design (pré-dimensionnement)**
  - Use of the schematic approach
  - Automatic link to Esacap solver : stationnary & transient routines
  - Post-processing :
    - Quick 2D curves
    - Excel file
    - 2D0 Systema file
    - Results on scheme



CAT

- **Suited to a small number of nodes (up to 40 – 50)**
- **Easy to use**
- **An alternative approach between Excel-based tools and detailed analysis software**
  - A key for software harmonisation inside Astrium
  - Typical users :
    - system engineers
    - thermal analysts (quick preliminary design)

Power & Propulsion : coupling with thermal tools

- **For some problems it is necessary to perform a coupling between the functional analysis tools and other tools like Systema/Thermica or ESATAN**

<u>In particular for</u> :

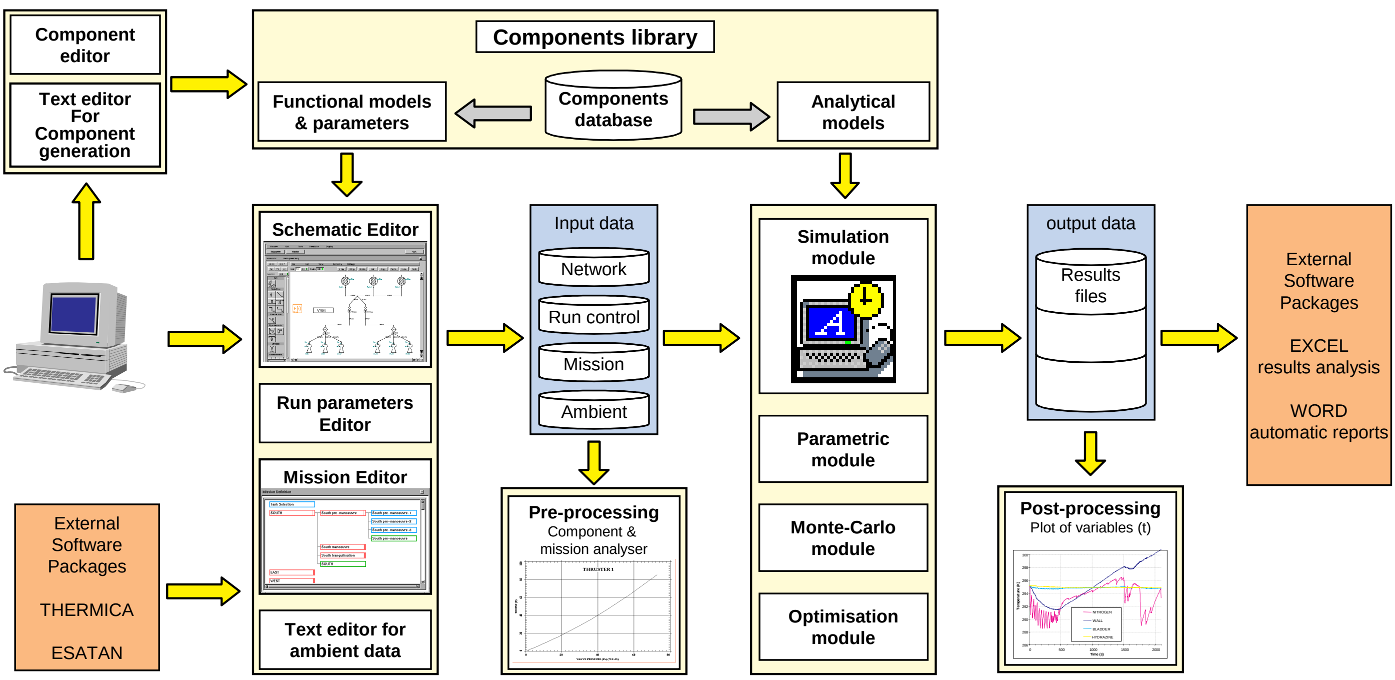
- **Power analysis to compute the :**
  - Solar flux during the mission
  - Radiative coupling between surfaces when there is a strong coupling between power performances and thermal environment (e.g. battery temperature)

  →Application : Power system performances analysis

- **Propulsion analysis when there is a strong coupling between the thermal environment and the fluid behaviour**

  →Application : hydrazine temperature calculation on Ariane 5

Power & Propulsion : Software architecture



Power : Power systems analysis

- **Power uses different models to define a PSS architecture**
  - solar arrays (with definition of thermal fluxes on orbit)
  - battery
  - regulation elements
  - electrical elements : resistance, diode, capacitance, …
  - thermal elements : conductive coupling, radiating coupling,…

  - Use of the mission module of **Thermica** and geometry to define the environment of the solar arrays (thermal)

- **Typical outputs of the software :**
  - current and voltage values at each node of the network
  - all the parameters specified by the models

Power – Interface with Thermica

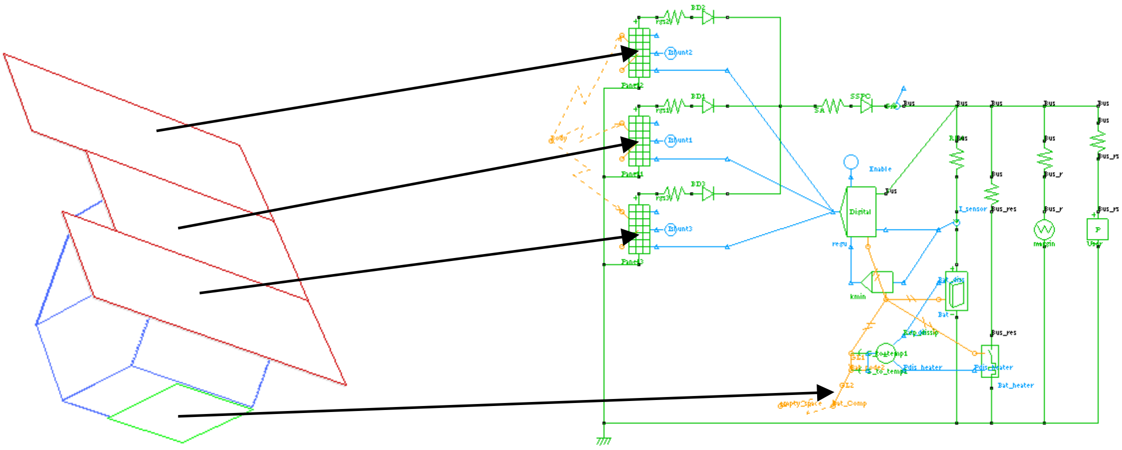
- **Evaluation of power sub-system performances requires the knowledge of the solar fluxes on the solar panels**
  - For any missions, the solar fluxes cannot be easily computed and require a geometrical description of the spacecraft, its mission and pointing
  - Moreover, for a detailed analysis, thermal and power behaviour are strongly coupled
    - E.g. the solar cell performances depend on the solar panel temperature and the solar panel temperature depends on the power converted in the solar cell

- **Need to implement an analysis tool coupling the power and thermal aspects**

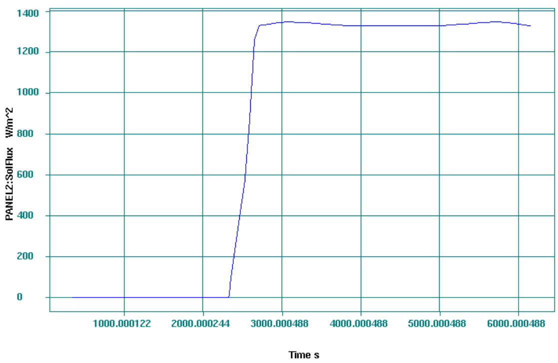
- **Well interfaced with Thermica for an easy use**

Interface between Thermica and Power

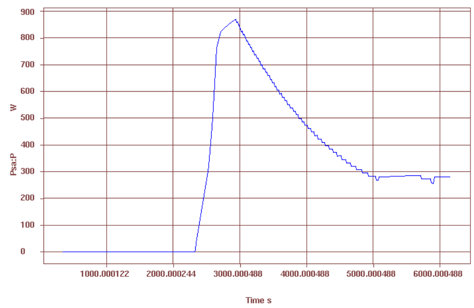
- The tool allows to manage a correspondence between the geometrical objects and the network components



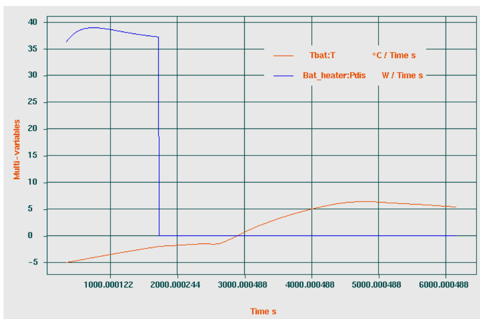
Power : Examples of results



Solar flux along the orbit



Total power from SA



Battery temperature and heater power

CAP : Propulsion systems analysis

- **CAP uses different models to define the propulsion system**
  - Thrusters (monopropellant, bipropellant, cold gas…) and nozzles
  - Tank (blow down and pressurised)
  - Vanes
  - Pipes

  - Interfaced with ESATAN to handle coupled thermal / fluid system

- **Typical outputs of the software :**
  - Overall performances of the propulsion system (impulse, consumed mass)
  - Temperature of the fluid in the lines

CAP : Example of application
Hydrazine temperature in the lines

- **The hydrazine temperature in the Ariane 5 Vehicle Equipment Bay (VEB) shall remain in a specified range**

- **Modelling of hydrazine temperature involved :**
  - A thermal model of the temperature in the tubing :
    - Conducto/convective flux in the fluid
    - Conducto/convective flux between the fluid and the line wall
    - Radiative flux between the line wall and the environment
    - Conductive flux between the the wall and the structure

- **The overall thermal network of the VEB environment and the coupling with the lines come from an ESATAN model of the VEB**

Computation of hydrazine temperature

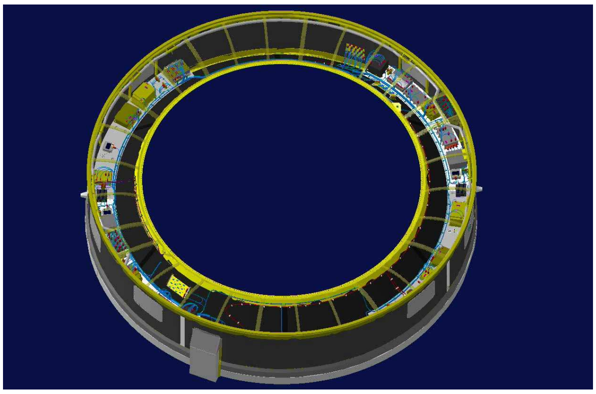
VEB ESATAN model

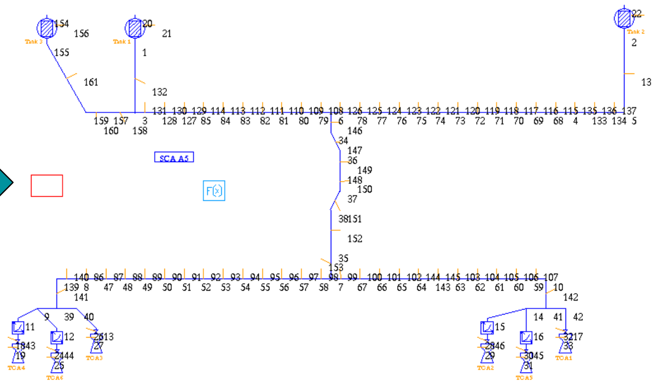
CAP model of VEB hydrazine tubing

+

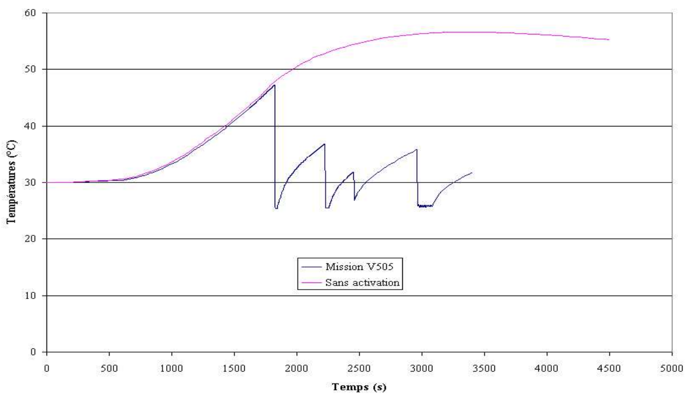
CAP model of VEB thermal network

Hydrazine temperatures

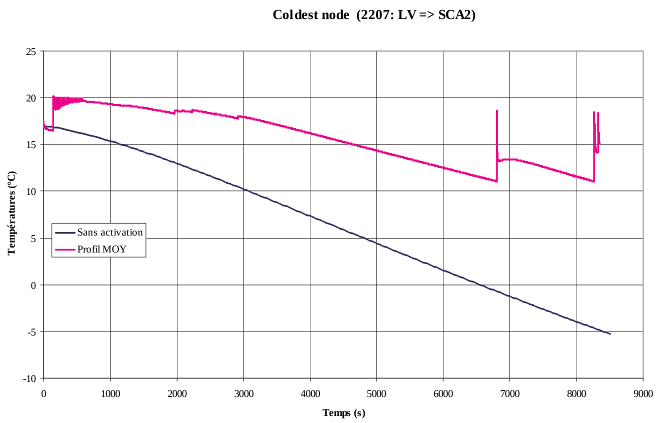




CAP : Examples of results



Hot case



Cold case

Appendix L: ALGOCAP: Assessment of Thermo Hydraulic Algorithms for Capillary Pumped Loops and Loop Heat Pipes

ALGOCAP:
Assessment of
Thermo Hydraulic Algorithms for
Capillary Pumped Loops and
Loop Heat Pipes

D. Labuhn
OHB

ALGOCAP

Assessment of Thermo Hydraulic Algorithms for Capillary Pumped Loops and Loop Heat Pipes

ESA Contract AO/1-3904/01/NL/LvH

Reinhard Schlitt, Dirk Labuhn, OHB-System AG
Valeri Vlassov, INPE, Brazil
Jay Ochterbeck, Clemson, USA (Consultant)
Olivier Pin, ESA/ESTEC (Technical Officer)

ALGOCAP Situation at OHB

- OHB is involved in several space projects, which include LHP for thermal control (AMS-02, NetLander, Rubin,…)
- LHP are purchased from outside according to our specification
- One of the main tasks at OHB: to analytically integrate the LHP into the spacecraft TMM

ALGOCAP Questions to be answered

- Are simulation tools available to incorporate Two-Phase Loops (TPL) systems into spacecraft thermal system analysis?
- If not, what can be recommend to reach this goal (create new, adapt existing tools)?
- What is the work sharing between supplier and user of TPL in terms of simulation tasks?

ALGOCAP Present Situation

- System companies and S/W developers are trying to incorporate detailed thermodynamic processes of a TPL into thermal control S/W tools at system level.
- ESATAN presently incorporates modules for evaporator, reservoir, filter.
- ESATAN / SINDA etc. have been originally developed to simulate thermal performance at subsystem and system level and are not easily adaptable to simulate detailed thermodynamic processes.

ALGOCAP Developer and User Conflict

- Incorporation of detailed thermodynamic processes at system level (for example an evaporator) may require knowledge of proprietary data from the TPL supplier, which could not be accessible to system companies.
- TPL developers often use semi-empirical relations for the loop layout (based on specific know-how and dedicated development tests). Again, these data may not be accessible to other companies.

ALGOCAP Developer and User Conflict (cont.)

- TPL developers are not acquainted with S/W at system level (ESATAN / SINDA). Simulation results obtained with these tools are not accepted as relevant performance data for their products.
- System S/W packages are developed to simulate spacecraft system with a large number of diffusion nodes which are based on large time steps to reduce CPU time.
- To simulate thermo-hydraulic processes at TPL level small time steps are required.

ALGOCAP Resulting Strategy

- Clearly distinguish simulation tasks at TPL supplier and user level.
- Detailed simulation of thermodynamic processes, which are performed by TPL supplier to build the loop, shall not be repeated at system level in comparable depth and with a (different) system tool.
- Detailed knowledge of the internal loop configuration are not needed at system level, i.e. wick dimensions, pore size, vapor space, reservoir characteristics, etc.
- System must rely on the delivered loop to meet system specifications, which are verified by supplier tests.

ALGOCAP Algorithm Development

- We decided to develop a self-standing S/W to simulate a TPL for use at system level.
- We concentrated our work on the predominant system interface, i.e. condenser/radiator interface.
- Other TPL features (especially evaporator) are represented with much lower detail, since they are needed to a lesser extent at system level and to avoid the use of propriety data.
- Representation of these features may be verified by TPL developer or through evaluation of test results.

ALGOCAP Algorithm Development (cont.)

- TPL S/W is based on the EASY 2000 package with some additional implementations:
  - Transient calculation.
  - Model is of nodal type.
  - Conductive and radiative links.
  - Liquid flow enthalpy links.
  - Surface pressure jump at interface.
  - Hydraulic equations are solved as quasi-steady-state.
- Different TPL S/W modules to represent TPL thermo-hydraulic behavior were first developed in C^{++} and are now transformed into MORTRAN language to reach compatibility to ESATAN.

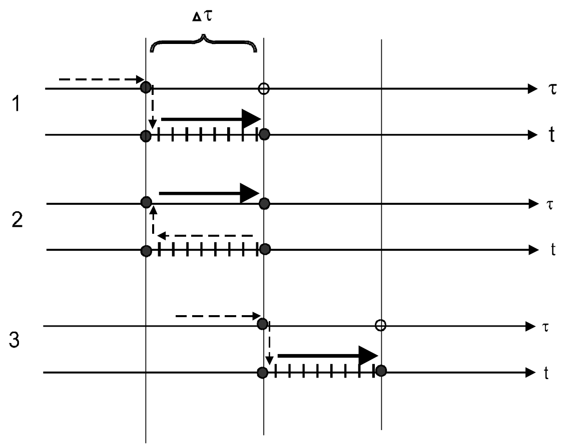
ALGOCAP Algorithm Development (cont.)

- In order to integrate the TPL model (called L-l or Low level model) with the system TMM (called H-l or High level model) an interfacing algorithm was developed.
- The algorithm simultaneously integrates the L-l (TPL) model of fine nodal breakdown with the H-l (TMM) model of coarse nodal breakdown.
- Interfacing algorithm of the present development is directed to both TPL condenser/ spacecraft radiator and TPL evaporator/ dissipated equipment as well.
- Emphasis is put on condenser/radiator as main interface to TMM at system level.

ALGOCAP Algorithm Development (cont.)

- Main idea of the interfacing algorithm (IFA) is to perform a separate and simultaneous integration of the H-l (TMM) with relatively large time step, and the L-l (TPL) model with relatively small time step.

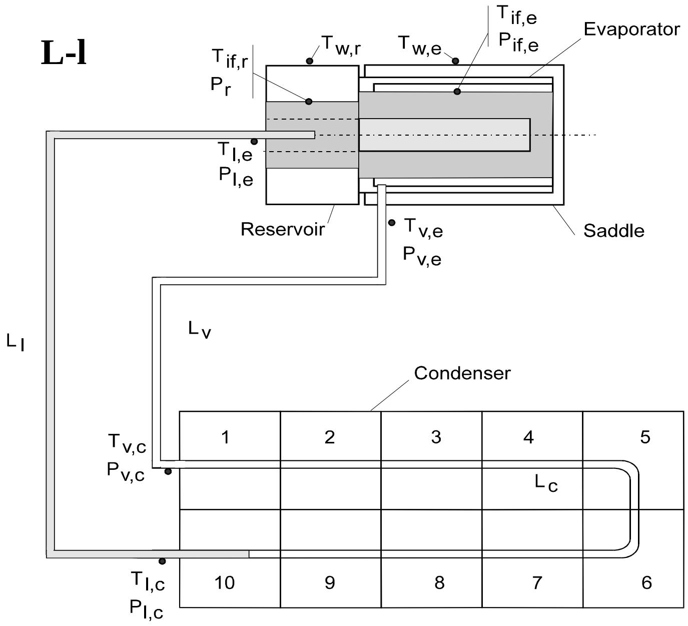
ALGOCAP Algorithm Development (cont.)



1. **Baseline are large time steps of the H-l model (TMM) $\Delta\tau$**
2. **The L-l model is executed for small time steps within the predicted duration of next large time step of H-l (phase 1)**
3. **During L-l execution the TMM must be switched off**
4. **Average interfacing heat fluxes are calculated, which are used by TMM for next large time step as additional heat fluxes**
5. **Next, H-l (TMM) is executed for the same large time step using heat fluxes supplied from L-l (calculated during phase1) (phase 2)**
6. **Process (items 2 to 5) is continuously repeated (phase 3)**

ALGOCAP Sample Case 1

L-l

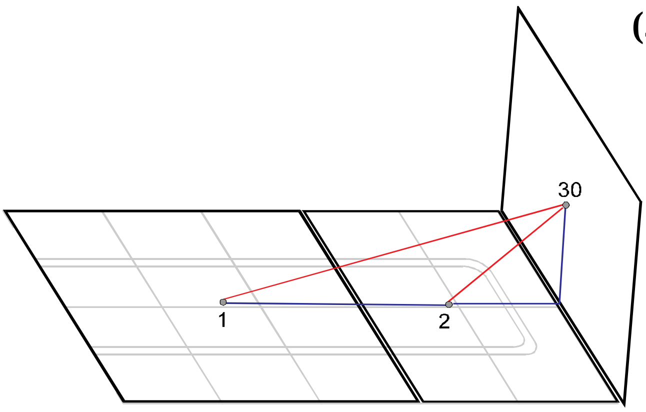


Analysis for simplified version of LHP (25 nodes at L-l and 3 nodes at H-l)

L-l:

- **Nodes 1 to 10 Radiator**
- **10 Fluid Line Nodes**
- **5 Evaporator Nodes**
  - **Payload Temperature**
  - **Evaporator Saddle**
  - **Vapor / Liquid Interface in the Evaporator**
  - **Reservoir**
  - **Vapor / Liquid Interface in the Reservoir**

ALGOCAP Sample Case 1 (cont.)

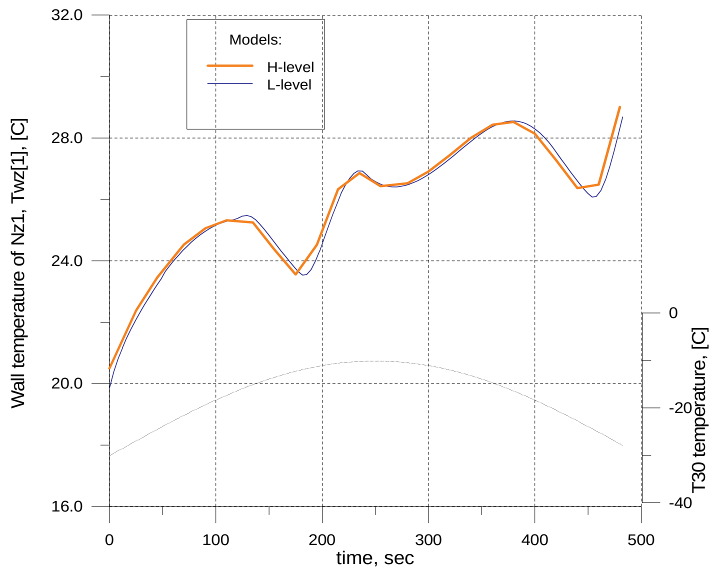


Analysis for simplified version of LHP (25 nodes at L-l and 3 nodes at H-l)

H-l:

- **2 Radiator Nodes**
- **1 Node of External Panel**

ALGOCAP Sample Case 1 (cont.)

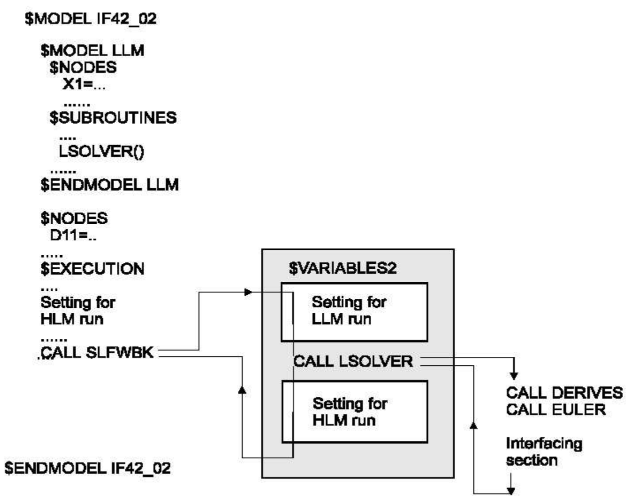


Results for simplified version of LHP (25 nodes at L-l and 3 nodes at H-l)

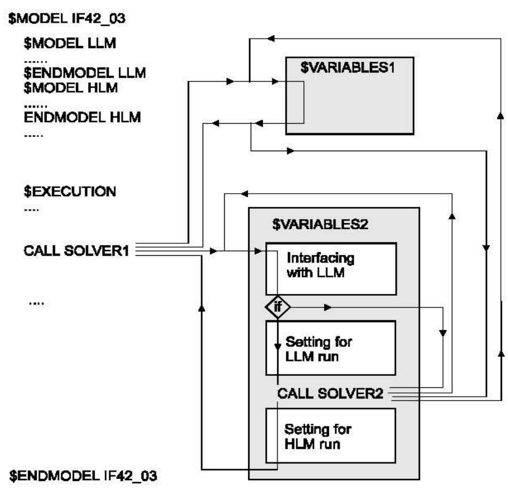
Conditions of Analysis:

- **Temperature of external panel (dotted graph) changed between 223 and 263K**
- **Inlet and outlet pressure of condenser varied rigorously**
- **Red graph depicts temperature of node 1 of H-l model**
- **Blue graph depicts average temperature of Nodes 1,2,3,8,9,10 of L-l model**
- **The correspondence of results for both models is very close**

ALGOCAP Implementation in ESATAN



solver:
HLM: SLFWBK or SLFRWD
LLM: any proprietary solver



solver:
HLM: SLFWBK or SLFRWD
LLM: SLFWBK or SLFRWD

ALGOCAP Implementation in ESATAN (cont.)

ESATAN: wish list

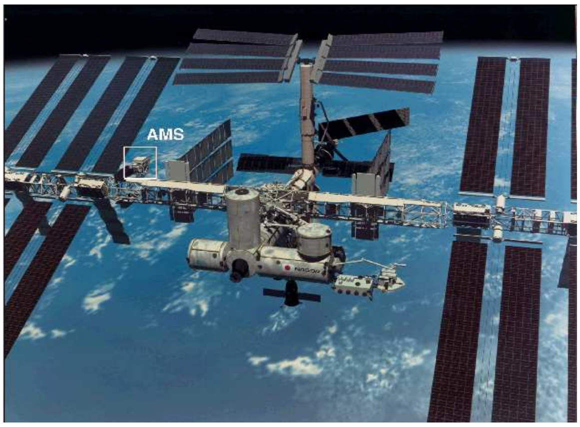
- **encapsulating feature within VARIABLES2 block**
  - cloning of solvers and control parameters
  - SLFWBK1 and SLFWBK2 using TIMEO1, TIMEO2 etc.
- **switching between LLM and HLM is done by activating and deactivating the respective nodes**
  - MDLON and MDLOFF at present can only be applied to diffusion nodes

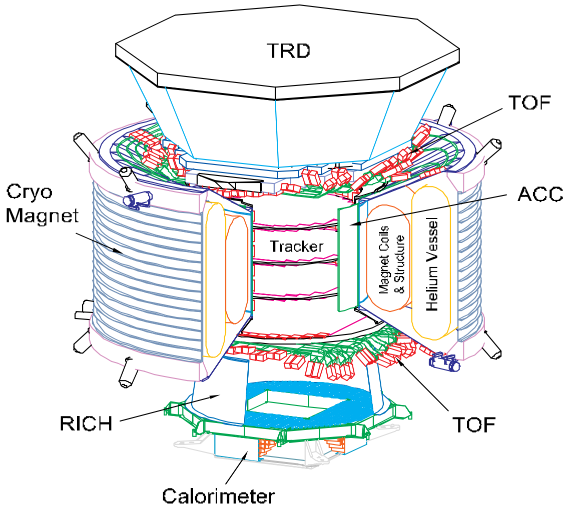
ALGOCAP Conclusions

- **An Interface Algorithm (IFA) for including the TPL model into the TMM model of higher level was developed from conception to practical realization.**
- **The developed IFA permits the the presentation of the TPL model at two levels (detailed L-l and coarse H-l); only the H-l TPL model with few diffusion nodes is integrated into the TMM at system level.**
- **TPL User can adjust his L-l TPL model by TPL Supplier test results (especially with respect to evaporator performance).**
- **Particular techniques for implementation of the developed IFA within existing ESATAN features have been developed and verified on prototypes.**
- **Modifications of ESATAN/MORTRAN subroutines have been developed and proposed in order to effectively perform the interfacing of the high and low level models.**
- **The developed analysis approach can easily be adapted to single phase/mechanically pumped loops.**

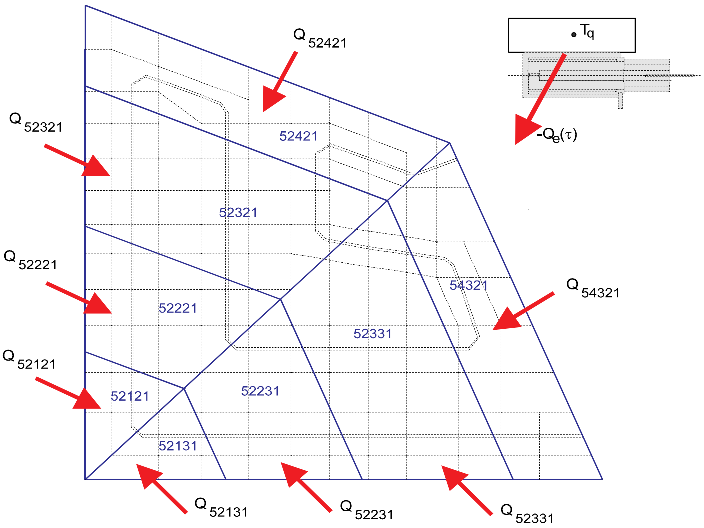
ALGOCAP Sample Case 2

- Study of the interfacing algorithm within the running project AMS-02





ALGOCAP Sample Case 2 (cont.)



Combining with TMM:

•AMS LHP model is presented by 9 nodes inside the system TMM (i.e. at H-l), which consists of about 1000 nodes in total

•Only these 9 simple diffusion nodes are being integrated in order to present the TPL at system level

•The L-l LHP model has 127 nodes; 112 of them belong to the radiator panel.

Appendix M: Use of ESARAD in MetOp SVM Thermal Testing Analysis

Use of ESARAD
in
MetOp SVM
Thermal Testing Analysis

E. Seward
Astrium Ltd.

Use of ESARAD in MetOp SVM Thermal Testing Analysis

By Elizabeth Seward & Ian Renouf
Astrium UK – Earth Observation and Science

astrium

an EADS joint Company with BAE SYSTEMS

Summary

1 Introduction

2 Analysis (initial test predictions)

3 Analysis (updated test predictions)

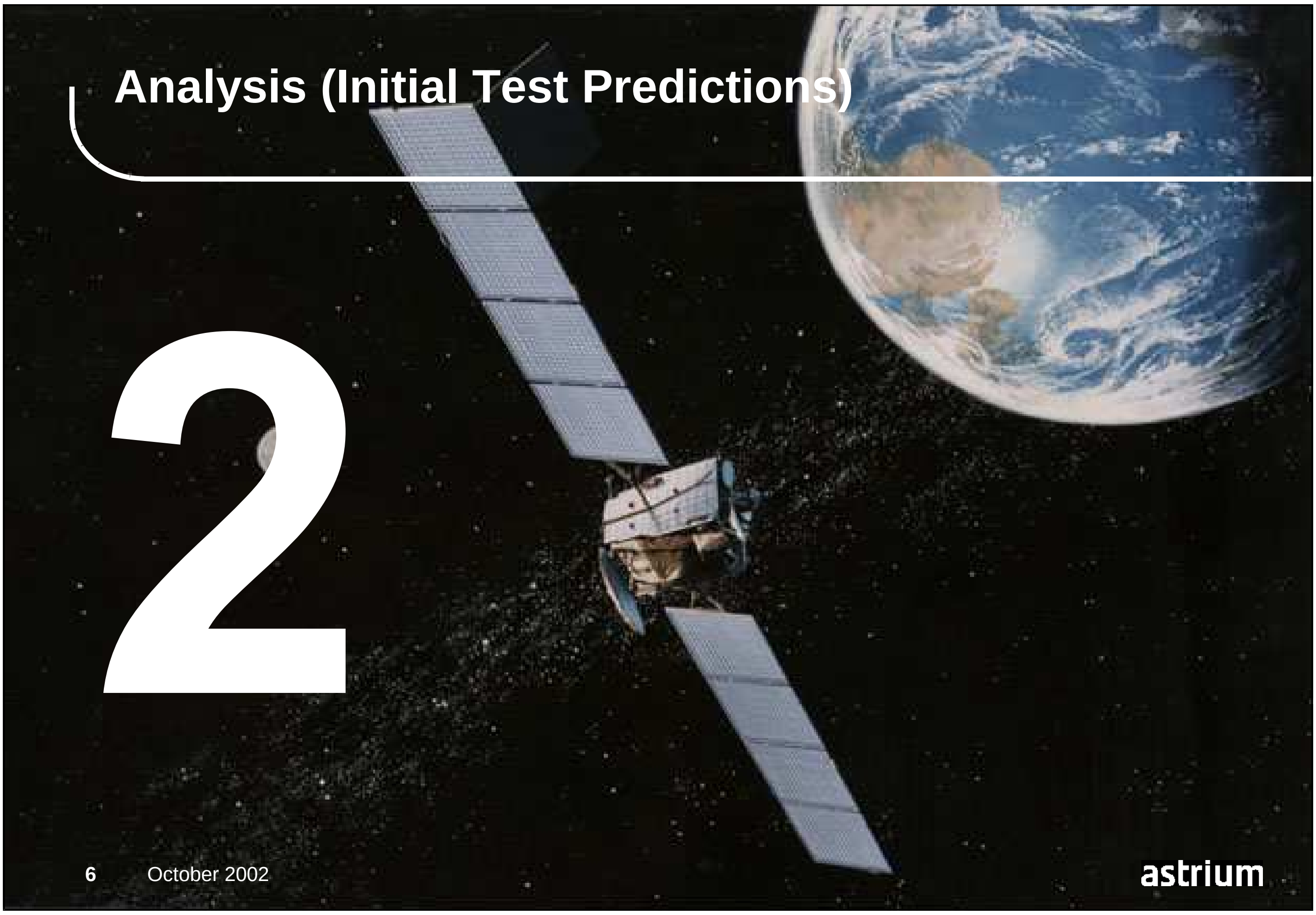
4 Conclusions

Objectives of Analysis

- Simulate the MetOp service module during TB/TV testing
- Use this model to define test specific hardware and test procedures
- Use the results of test to modify the model so that the results of the test correlate with the results of the analysis
- Transfer this correlated model to the flight analysis model and calculate final flight predictions

Initial Resources/Models

- Detailed model of MetOp SVM in ESARAD v3.2.7 in flight configuration
- Simple model of SIMLES chamber at INTESPACE in SYSTEMA
- Copy of ESARAD v3.2.7 running on HP Unix operating system

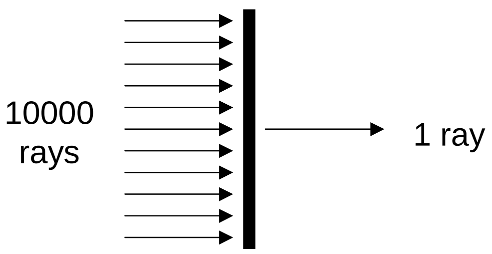


Initial ESARAD Test Model

- Strip down flight model to a test configuration
- Convert SIMLES model into ESARAD
- Put models together to create test model
- Add models to represent the test adaptors and simulators.

Problems (1): Transmissive Surfaces

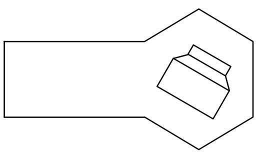
Effect of transmissive surface in Monte-Carlo raytracing solution



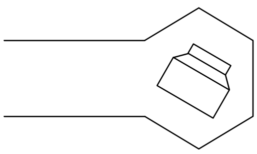
Result: Highly inaccurate solar flux results for model

Problem

Use 2 models



Model to calculate radiative couplings 'With Mirror'



Model to calculate solar fluxes 'No Mirror'

Solution

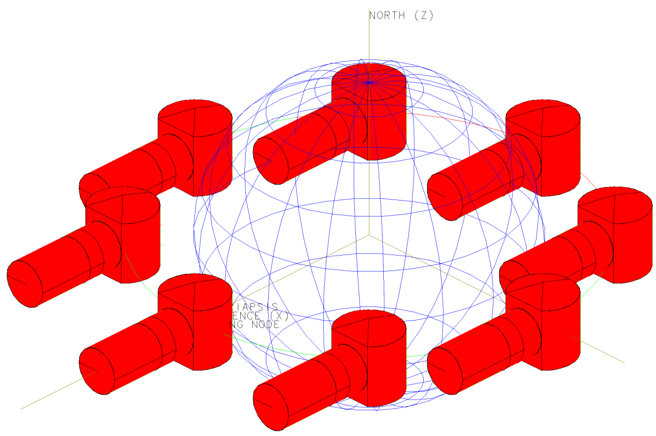
Problems (2): Transient Simulation

Problem:

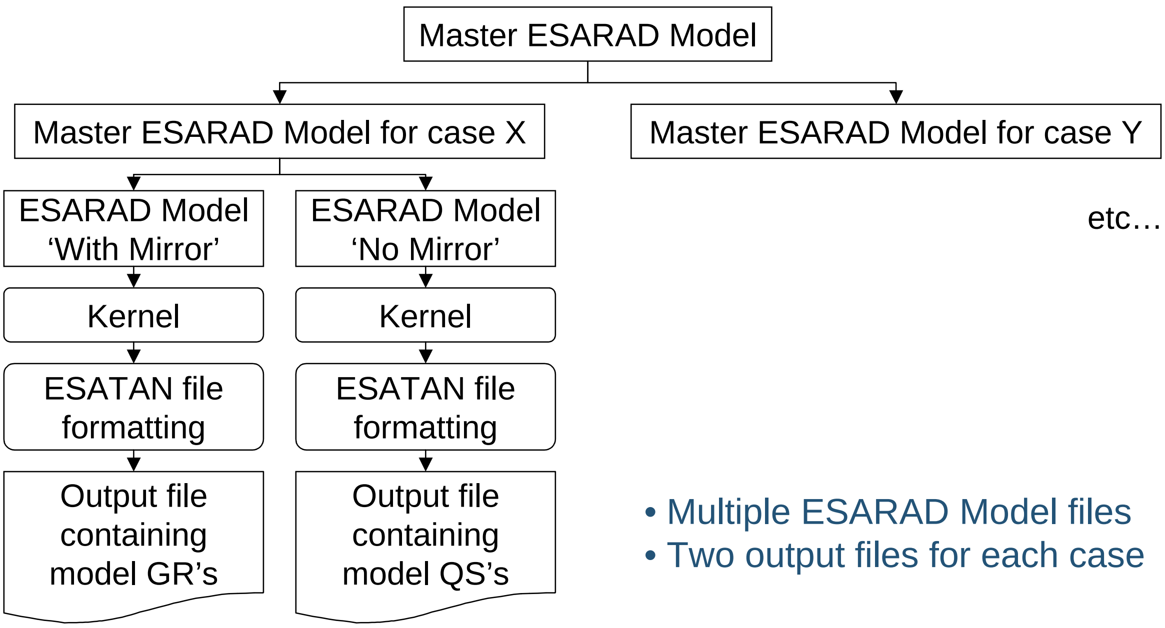
- How to simulate the rotation of the spacecraft for the transient test phases

Solution:

- Assemble the SVM and SIMLES with the SVM as the moving body and orientated towards the Planet
- Put the model in a sun oriented orbit with the chamber mirror pointed towards the Sun
- Set the orbit parameters so that the orbit is equatorial, with a time period equal to the rotation period of the satellite in the test chamber



Final Model Structure

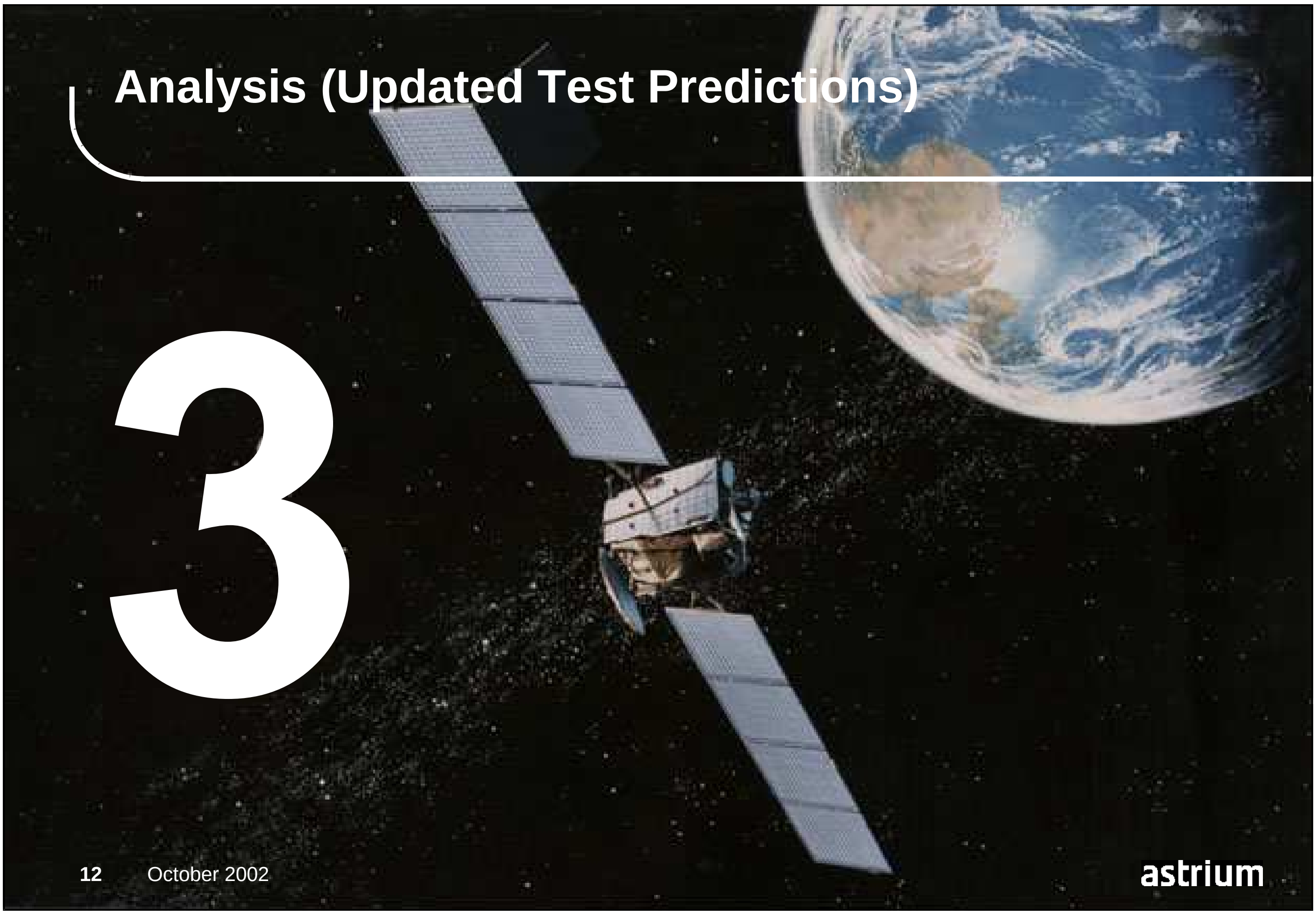


- Multiple ESARAD Model files
- Two output files for each case

Update to ESARAD v4.2.10

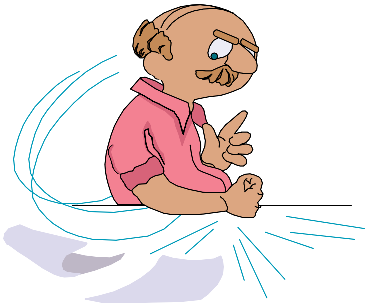
Upon the release of ESARAD v4.2.10 the model was modified to work in the new version. The following actions were performed

- The geometry modified to work fully compliant with the new version
- The Kernel was updated and run in the new version
- The ESATAN file formatting was updated and run in the new version
- The output from the ESARAD v4.2.10 was checked and verified against the results from v3.2.7



Update Model to Final Test Specification

- 12 months later the model needed updating due to changes to the test specification, and to prepare to perform test correlation
- v4.3.2 of ESARAD now in use



Upon running the ESARAD files it is discovered that they no longer produce an output for radiative couplings and solar flux

An investigation is launched to uncover the problem.

Simultaneous a review of the procedure for running the model is performed to see if a more efficient solution exists

Update ESARAD Kernel File

- A review of the Kernel file shows that it is a v3 kernel for a standard orbital analysis that has been modified to work in v4.
- The Kernel file is seen to contain code that adds no value to the model or performs unnecessary tasks that slow down the analysis and could be at fault for the problem
- Kernel file is rewritten to specifically to run the test analysis with all unnecessary code removed

Conclusion:
Model still does not work but model will run in half the time when the problem is found

Implementation of multiple 'ASSEMBLY' commands

- **Techniques learnt from other programs shows that multiple 'ASSEMBLY' commands can be stringed together to provide a model with multiple degrees of freedom that can be controlled by user defined code in the Kernel**

New Top Level Model Structure

SVM_Moving
Ref Comp: simles_support
Moving Comp: SVM_assembly
XR: Trans_Rotation

SIMLES
Ref Comp: simles_chamber
Moving Comp: simles_mirror
XT: Mirror_Position

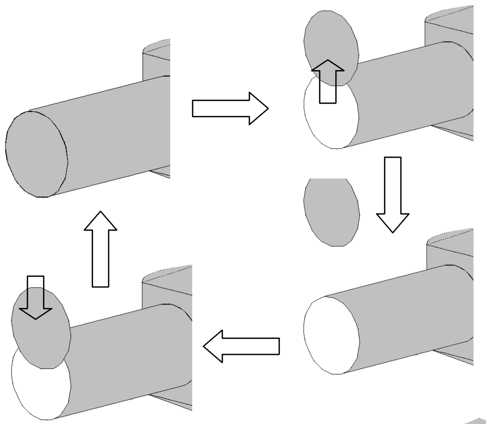
SIMLES
Ref Comp: SIMLES
Moving Comp: SVM_Moving
YR: Tilt_Angle

Where:
Trans_rotation,
Mirror_Position &
Tilt_Angle are REAL
variables

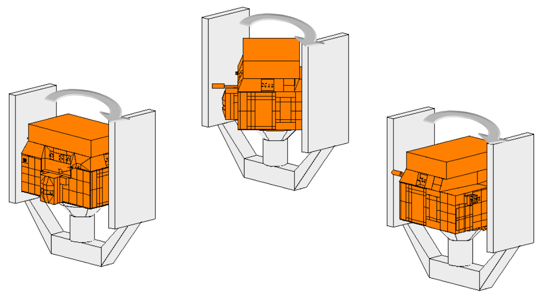
Conclusion:
The model now generates results. The problem appeared to lie with the planet orientation of the SVM

Visualisation of 'ASSEMBLY' actuations

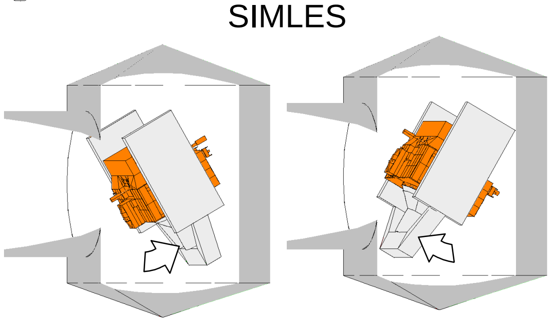
SIMLES Assembly



SVM Moving



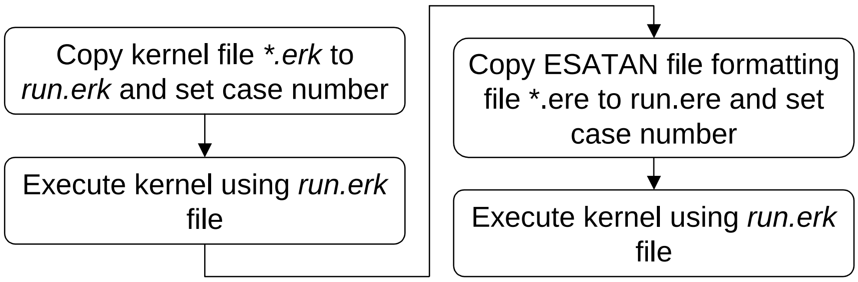
SIMLES



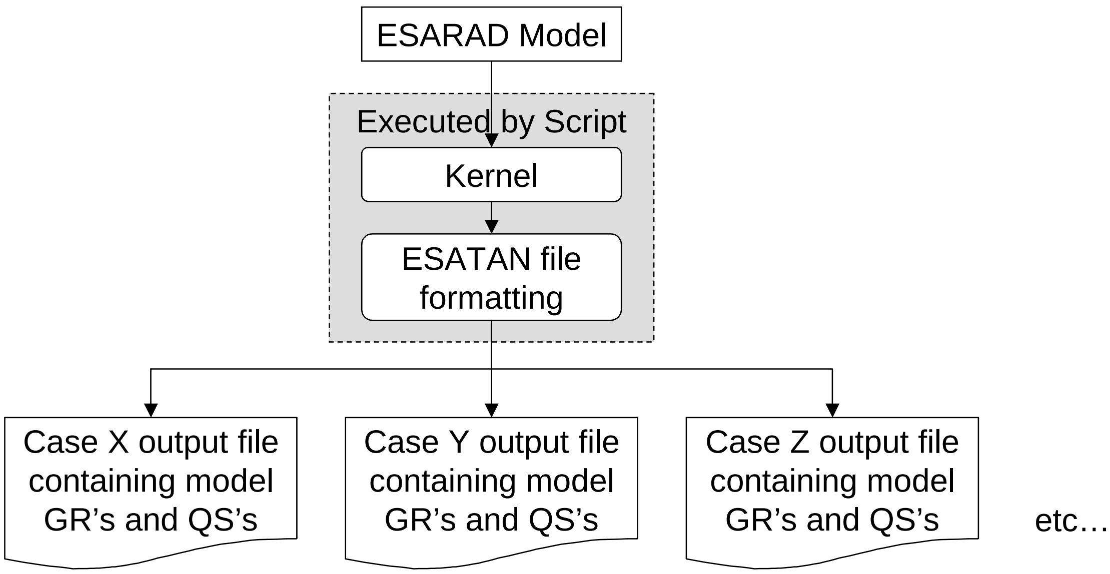
Addition of Script to Run Analysis Cases

- **Astrium UK defines its ESARAD kernels for multiple cases in a single file, switches are embedded in the file to run the parameters desired for each case.**
- **Experience of UNIX has shown that short script files can be used to run models. Implementation of a script allows any case or combination of cases can be set to run sequentially very quickly (and accurately).**
- **By combining these 2 techniques together we now have a system that runs as many ESARAD cases for a model as we like, whilst using and producing the minimum number of files and data.**

Script file logic



New Final Model Structure



- Simple model structure
- One output file for each case

Verification: Checking Steady State Fluxes

- The fluxes from the v4.3.2 run were compared to the values from v4.2

Case 1.1
Hot Fixed

Nodes	Original	V4.3.2	Difference	Percentage Difference
11171	20.926	20.649	-0.2779	1.33%
11401	2.279	2.274	-0.0056	0.25%
11412	3.207	3.215	0.0079	0.25%
11415	5.356	5.360	0.0042	0.08%
11452	3.564	3.559	-0.0050	0.14%
11455	7.685	7.675	-0.0096	0.13%
13312	28.142	28.142	-0.0005	0.00%
13314	11.847	11.798	-0.0486	0.41%

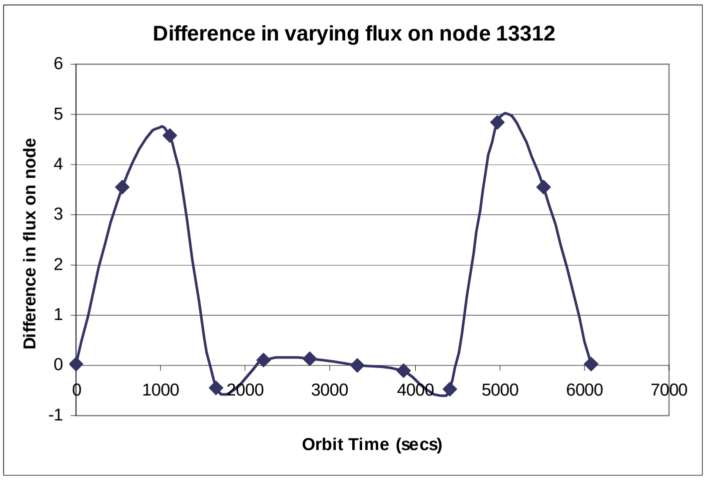
- The comparison was repeated for the other steady state cases with similar results

Verification: Checking Transient Fluxes

- Again the fluxes from the v4.3.2 run were compared to the values from v4.2

Case 1.2
Hot Transient
Node 13312

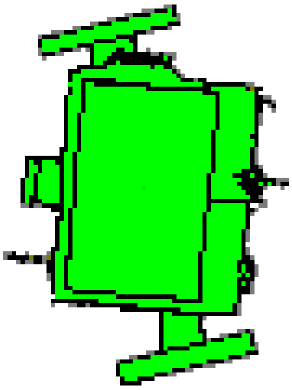
Original	V4.3.2	Diff	% Diff
88.393	88.410	0.0164	0.02%
70.433	73.975	3.5417	5.03%
28.169	32.741	4.5722	16.23%
3.812	3.359	-0.4535	11.89%
0.299	0.394	0.0953	31.84%
0.660	0.779	0.1191	18.04%
0.746	0.753	0.0071	0.96%
0.286	0.182	-0.1032	36.12%
4.236	3.767	-0.4696	11.08%
27.844	32.699	4.8549	17.44%
70.447	73.988	3.5417	5.03%
88.393	88.410	0.0164	0.02%

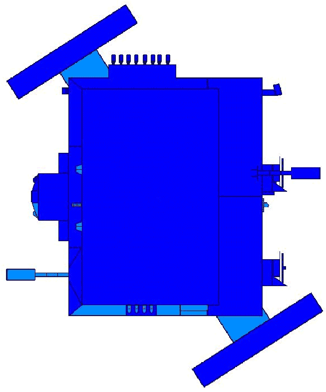


This variation in the fluxes is due to the different kernel files

Verification: Visualisation of Kernel

In these animations, support structure is rotated around the SVM





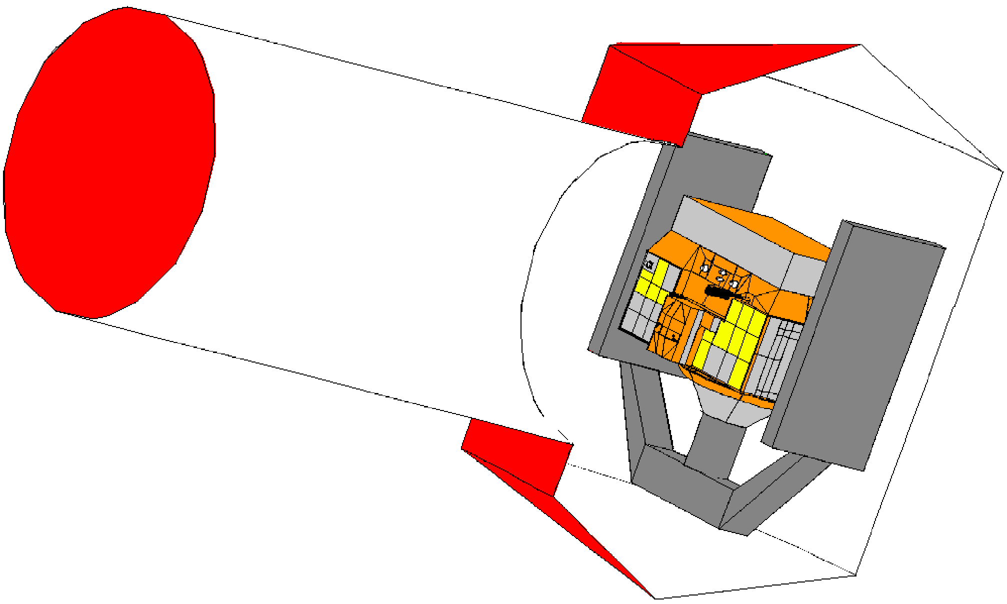
Old Kernel

• The wobble seen is due to the a slight variation in step angle when the SVM is Earth pointing and its rotation axis is not perpendicular to the pointing direction

New Kernel

• The kernel file moves the SVM by a defined angle each time

Visualisation of Final Model



MetOp SVM in the simles chamber

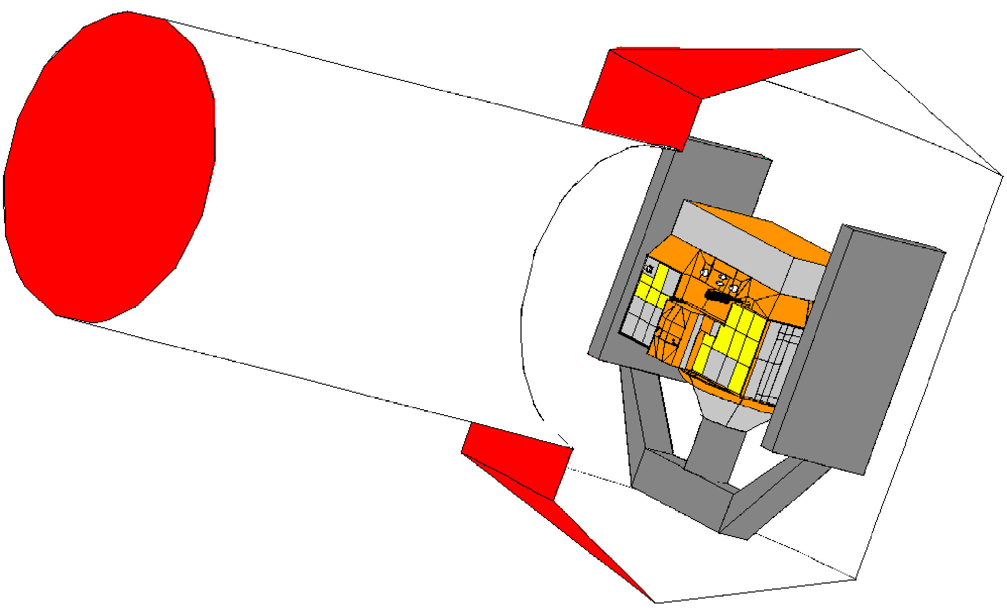
Achievements

- **The model works and generates the correct results**
- **The number of models has been reduced**
  - From 10 down to 1
- **The file/model structure to run the model for all cases has been simplified**
  - A single model makes it much easier to implement and control geometry changes
- **It is now much easier to make modifications to the model and re-run cases as desired**
  - The time taken and effort required to run the model is greatly reduced
- **This solution has been proven to be compatible with ESARAD v5**
  - The same problem should not occur in future

Outstanding Issues

- ESARAD has not yet been shown to handle transmissive surfaces in a way that will produce results in an acceptable computation time.
- It is not possible to visualise transient ESARAD kernel runs that use pointing defined by user code in the kernel file in the same way as predefined ESARAD pointing. i.e. you can not visualise the complete orbit in the same orientation as that used to generate results.
- Experience has shown that there are normally compatibility issues when ESARAD (and ESATAN) are upgraded to the new versions that normally require small modifications to be made to the models. How can the occurrence and effect on projects of these problems be reduced in future?

Questions?



MetOp SVM in the simles chamber

Appendix N: ESA Harmonisation and User Survey

ESA Harmonisation

and

User Survey

HP. de Koning
ESTEC/TOS-MCV

ESA Harmonisation & User Survey

Thermal and Space Environment Analysis Tools and Interfaces

Hans Peter de Koning (ESA D/TOS-MCV)

Charles Stroom (ESA D/TOS-MCV)

Éamonn Daly (ESA D/TOS-EMA)

John Sørensen (ESA D/TOS-EMA)

Luca Maresi (ESA D/IMT-THH)

Background on the disciplines

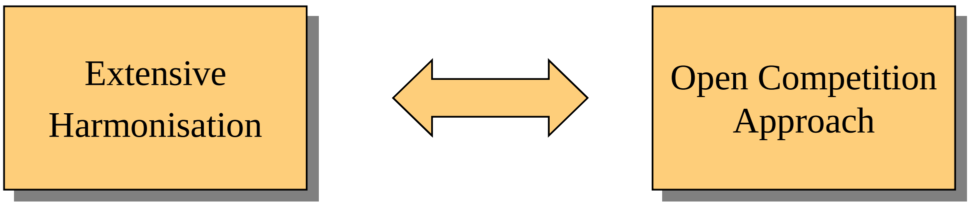
- The domain comprises:
  - → Spacecraft thermal control: managing internal and external heating and cooling as well as temperature ranges for spacecraft parts
  - → Space environmental effects: high energy radiation, plasmas, small sized debris and meteoroids
- During all mission phases
- Different disciplines, different models, however sharing common needs:
  - → Spacecraft shape (external surfaces) and material properties
  - → Orbit trajectory, attitude, pointing, rigid body kinematics
  - → Shared solution algorithms (e.g. ray-tracing)
  - → Similar needs to exchange data with CAD and other engineering disciplines
- It is space-specific (i.e. no terrestrial equivalent):
  - → Thermal: radiation dominated (vacuum); limited convection (vacuum, zero gravity); wide temperature ranges and thermal cycling
  - → Space environment: energetic particles, atomic oxygen, space debris, contamination, ...

Software tools are fundamental for all engineering analysis

- For design, development, verification and in-orbit operations
- Many tools are in actual use:
  - → Fully commercial (NASTRAN, Mentor Graphics, etc.); wide range of applications; many users
  - → Space-specific tools (thermal, space environment); very specific; limited number of users (number of sites in Europe ~100 max, in US few hundred, rest of world ?)
  - → In-house developments; often to complement other tools in use, or to capture specific company expertise
- PDE (product data exchange) of models, results, material and other data, is an ever growing concern:
  - → To support multi-disciplinary design and development, collaborative engineering
  - → To support efficient data exchange between partners

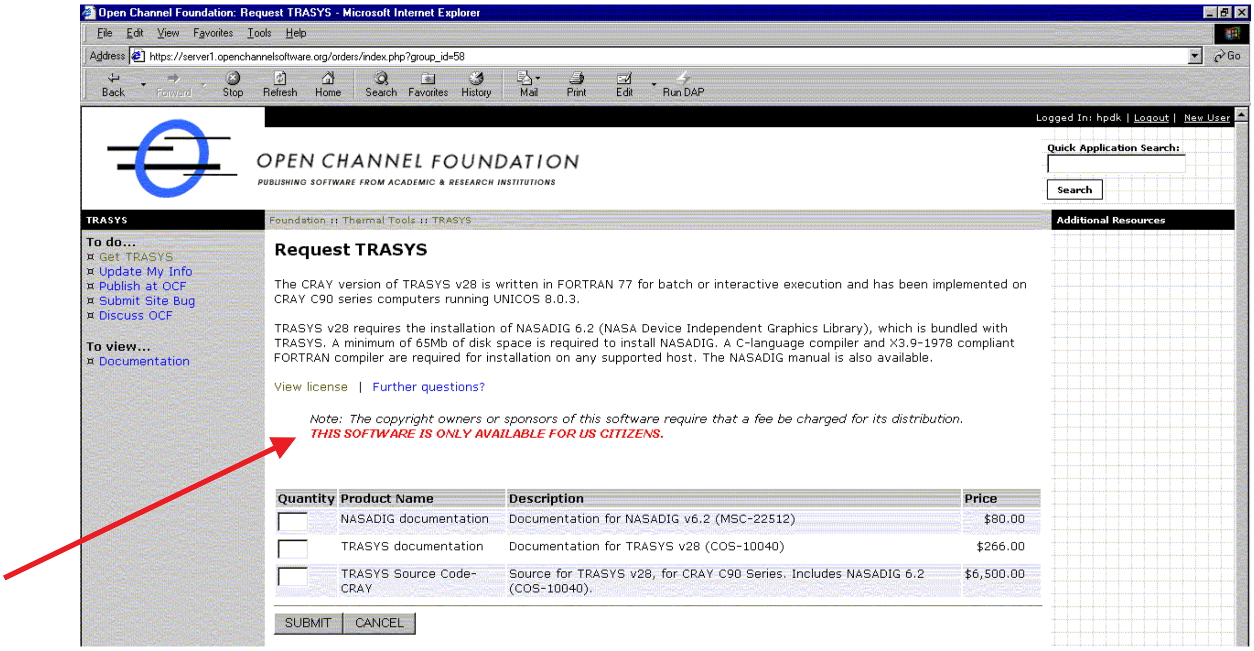
The Harmonisation Effort

- Technology mapping meeting 24-Apr-2002 – widely different views:



Consensus:	Strategic issues:
Standards for exchange of models and data are important Several current tools are ageing and in serious need of replacing	Ensuring long-term availability Intellectual Property Rights (IPR) Tools that can be affected by export restrictions Arguments in favour of or against promoting “ESA” tools Use of Open Source Software (OSS)

Illustration of strategic issue
Export restrictions



Towards a Roadmap

- Topics
  - → Detailed medium/long term strategy
  - → Expected added value
  - → Proposed development approach
  - → Schedule and cost
  - → Risk analysis
- Roadmap options:
  - → (1) European institutions adopt a hands-off approach except to facilitate and promote standards as a mechanism for harmonisation
  - → (2) European institutions actively pursue a harmonised approach of coordinated developments of standards and generic analysis software components (“toolkit”)
- User survey and initial results

Roadmap Options

	Option 1 (hands-off)	Option 2 (harmonised)
Strategy	Establish analysis & data exchange standards	Establish analysis & data exchange standards Make a coordinated development of a generic "Toolkit"
Development Approach	ECSS Working Group Development and validation by tool developers on their own funding Ad-hoc developments by agencies (only for specific needs)	Overseen by "harmonisation board" of stake-holders and funded by appropriate means (e.g. GSTP, Nat. funding, EC) Open source approach is an attractive option
Schedule & Cost	~200k€ (ESA budget) + industry costs, 1-2 years	~2M€ over 3-5 years

"Toolkit" Content

- Possible elements of a generic "Toolkit" for building of domain specific applications – needs addressed:
  - → Model construction, including kinematics, meshing, idealisation
  - → Database(s) of (environment) models, material properties
  - → Data exchange (between thermal/space environment tools, CAD, other disciplines)
  - → Visualisation
  - → Post-processors
  - → Solvers (e.g. ray-tracers)
  - → Graphical user interface
  - → Orbit generators
  - → Domain specific modules (e.g. thermal conductor generation)

Expected Outcome

	Option 1 (hands-off)	Option 2 (harmonised)
Short term	Standards may be accepted (debatable)	Standards are accepted and a generic "toolkit" is developed applying the standards
Medium and long term	Industry will rely on commercial or internal developed tools	Industry will have stable and maintainable tools based on common standards and common software elements
Added value	Industry free to make their own tools	Rapid developments avoiding duplication

Risks / Advantages

	Option 1 (hands-off)	Option 2 (harmonised)
Risks	Standards not fully adopted Duplication of tools Gaps in tools Costly maintenance Some tools can be affected by export restrictions	Slow consensus building Insufficient mandate Insufficient financial means

Risks / Advantages

	Option 1 (hands-off)	Option 2 (harmonised)
Advantages	Possible rapid response to new user requirements	Rapid developments when toolkit available Industry can concentrate on domain specific part of tools Cost-sharing (also for maintenance and validation) Data exchange at toolkit level

Open Source Software (OSS)

- The OSS development and distribution model characteristics:
  - → The IPR is governed by a license - NOT necessarily public domain
  - → The source code is made available
    as well as any other components needed to build the software
  - → The user is free to modify and re-distribute the software
  - → The software is NOT necessarily provided free of charge
  - → Improvements are usually fed back to a central maintainer of the software and applied in a configuration controlled way (mostly using GNU CVS)
  - → The development is usually guided by a dedicated (formal or informal) membership organisation

Open Source Software (OSS)

Advantages	Disadvantages
Users can quickly adapt software Users can develop special purpose applications Ensured long-term availability Many existing OSS modules of high quality Reducing (direct) cost	May discourage some industries Vendors need to change business model

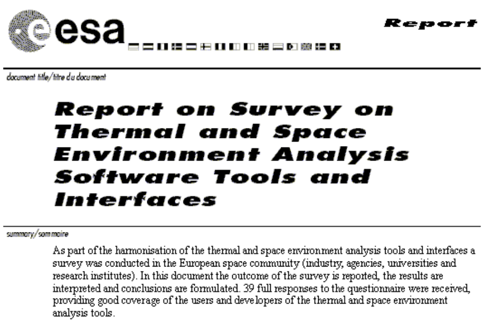
User survey

- http://www.estec.esa.int/thermal/survey/tse_sw_harmonisation_survey.html
- Purpose:
  - → Solicit more input from users on content and principles of future developments in order to obtain a good foundation for the harmonisation effort
- Statistics
  - → Survey performed June 2002
  - → 41 responses of which 39 answered in full
  - → All major players in participated - good mix of prime and smaller contractors

category	*invited*	*responded, but not interested*		*responded fully*	
agency	19	1	5.3%	4	21.1%
industry	60	1	1.7%	22	36.7%
university/institute	20	0	0.0%	5	25.0%
total	**99**	**2**	**2.0%**	**31**	**31.3%**

User survey report

- Complete (anonymised) report was made
- Available upon request from Hans-Peter.de.Koning@esa.int
  - → Will be distributed as PDF next week (28-Oct / 1-Nov)


esa — Report

document title/titre du document

Report on Survey on Thermal and Space Environment Analysis Software Tools and Interfaces

summary/sommaire

As part of the harmonisation of the thermal and space environment analysis tools and interfaces a survey was conducted in the European space community (industry, agencies, universities and research institutes). In this document the outcome of the survey is reported, the results are interpreted and conclusions are formulated. 39 full responses to the questionnaire were received, providing good coverage of the users and developers of the thermal and space environment analysis tools.

Main conclusions from user survey (1)

- 1. Data exchange based on open standards, supported by reliable and verified interface software, is priority number one and should be co-ordinated and funded by ESA. There is almost unanimous agreement on this.
- 2. Apart from data exchange, the reliability, robustness and proper validation of tools and (space environment) models are deemed of the utmost importance.
- 3. Data archiving is perceived as a less important issue.
- 4. The respondents have quite varying opinions with respect to the need and benefits of the development of a generic toolkit to support thermal and space environment analysis tools.:
  - → those who are in favour, and,
  - → those who think it should be left to commercial developers / vendors.
  - → A small majority sees the benefits of generic toolkit components, mainly users / not vendors.

Main conclusions from user survey (2)

- 5a. For a possible generic toolkit the following are the most desired functionalities:
  - → data exchange / open interfaces
  - → the material properties database,
  - → pre- and post-processing / visualisation / GUI modules
- 5b. The following functionalities received the lower scores:
  - → configuration and version control
  - → scripting modules (command language)
  - → model abstraction and idealisation
  - → high performance computing
- 6. Users do not want a single big tool.
- 7. Of the various analysis methods, the Monte-Carlo ray-tracing, lumped parameter and finite element analyses techniques are needed most.

Main conclusions from user survey (3)

- 8. There is broad concensus that is important that European space organisations have guaranteed and continued access to the space engineering tools.
- 9. There is a clear preference that ESA keeps on funding development of specific tools. There is little concern that funding by ESA will distort a the market competition.
- 10. For a future development of a generic toolkit there is clear preference that this shall be managed through a purposely created "management board", in which users and ESA should participate.
- 11. The respondents have widely varying opinions with respect to with whom the Intellectual Property Right (IPR) of a future generic toolkit should be vested and on whether this should be an open source software arrangement.
  - → Statements range from "*I think Open Source arrangement is the most efficient way to develop applications at low costs*" and "*open source is the best concept wrt. future developments/extensions of any software*" to "*Scepticism with respect to open source solutions*" and "*Q111,Q112,Q113 are nice,but little acceptance by commercial dept. in industry*".
  - → There seems to be a slight preference for either IPR vested with a neutral body or a kind of Community Open Source arrangement.

Main conclusions from user survey (4)

- 12. There is agreement that if the IPR should be vested with a neutral body it should be with ESA.
- 13. Maintenance should be the responsibility of the developer of the individual tools.
- 14. A large majority (over 70%) is willing to use Open Source Software tools. Conditions for its use are good validation, maintenance and configuration control.
- 15. About half the respondents would participate in the maintenance of Open Source Software, the other half would not.
- 16. The range between 1 and 10 kEuro per seat per year is considered an appropriate fee for a thermal or space environment analysis tool.

What next?

- Harmonisation roadmap is developed by ESA for presentation / approval December 2002 Harmonisation Meeting with the national delegations
- Roadmap will focus on harmonised development approach
  - → (1) Open standards for model / data exchange and software components to implement interfaces (without dependence on COTS third party software)
  - → (2) Generic “Toolkit” of OSS software components plus supporting organisational structure
  - → (3) Time, schedule and funding

Appendix O: Use of TSS as a neutral format for geometry model conversions: an alternative to STEP-TAS

Use of TSS
as a neutral format for
geometry model conversions:
an alternative to STEP-TAS

H. Peabody
Swales Aerospace

USE OF TSS AS A NEUTRAL FORMAT FOR GEOMETRY MODEL CONVERSIONS: AN ALTERNATIVE TO STEP-TAS

Hume Peabody
Swales Aerospace

Outline

- **Background and Introduction**
- **Common Thermal Radiation Analysis Codes**
- **Geometry Conversion Characteristics**
- **Examples of Model Conversions performed by Swales**
  - **Details of obstacles overcome**
- **Conclusions and Future Plans**

Background

- Many thermal radiation analysis codes available in U.S.
  - Not all companies use the same analysis codes
  - International organizations may use additional codes
  - May require model conversion between formats
- All thermal subsystems must be analyzed together using one analysis code
- Two neutral formats proposed for geometric radiation model conversion
  - SET-ATS and STEP-TAS
    - Little acceptance in U.S
  - U.S. codes import/export TRASYS
- Neutral format generally agreed to the best approach for model conversion
- Specific format to use for neutral format not well established

Introduction

- STEP-TAS under development by NASA/ESA as a neutral format
  - After number of years, not reached maturity
  - No industry standard exists
- A neutral format (in general) should support the characteristics and features of a majority of similar codes.
- Thermal Radiation Analysis Codes require the following defining characteristics:
  - Base set of Primitive Shapes
  - Sizes and locations in 3D space
  - Optical Property Representation
  - Nodal Representation
- TSS can replicate surfaces from most other codes
- TSS is a viable neutral format

Available Radiation Analysis Codes

SWALES AEROSPACE

- Common thermal radiation analyzers include:

Code	Developed By	Distributed By	Output Format	Comments
TSS	NASA	SpaceDesign	ASCII	
ESARAD	Alstom	Alstom	ASCII	ESA standard
Thermica	Matra Marconi (now Astrium)	Astrium Network Analysis	ASCII	Network Analysis is U.S. distributor for Thermica
Thermal Desktop	Cullimore & Ring	Cullimore & Ring	Compr, Binary	Unable to access surface data in AutoCad DWG
TMG	MAYA HTT	MAYA HTT	ASCII	Revolved surfaces not yet supported
TRASYS	NASA	NASA	ASCII	Declining usage

Available Converters

SWALES AEROSPACE

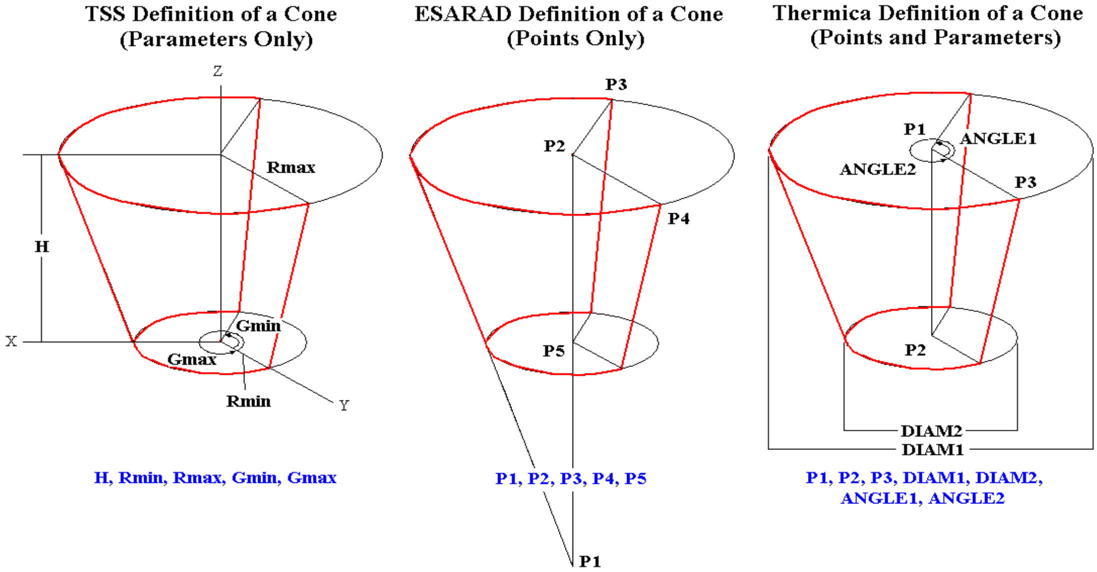
- Import/Export Capabilities of codes

Code	Imports	Exports	Primary User
TSS	TRASYS	TRASYS	United States
ESARAD	SET-ATS, STEP-TAS	SET-ATS, STEP-TAS	Europe
Thermica	SET-ATS, STEP-TAS	SET-ATS, STEP-TAS	Europe
Thermal Desktop	TSS, TRASYS, STEP-TAS	TSS, TRASYS, STEP-TAS	United States
TMG	TSS	TSS, TRASYS	United States
TRASYS	None	None	United States

Geometry Conversion

- No simple way to convert between U.S. and European based codes
- Three major aspects must be considered for geometry model conversion
  - Geometric Representations and Shapes
  - Optical Property Representation
  - Nodalization and Active Sides for Thermal Math Models
- Swales Aerospace developed computer routines in Visual Basic to convert between TSS and (Thermica or ESARAD)
  - These routines used with great success on the MetOp, SECCHI, EOS-Aura, and EIS projects

Geometry Representation



- Each code has its own method for defining objects.
  - Series of parameters (e.g. trx, rot1, xmin)
  - Series of specific points (e.g. 4 corners of a quadrilateral)
  - Hybrid of the above two methods, using 3 points to define an orientation and parameters to define dimensions and sizes

Geometric Shapes

- Not all codes include the same base set of primitive shapes
- The table below provides a listing of some of the more common shapes, which codes support them, and how they are represented

Type	TSS	ESARAD	Thermica	Thermal Desktop	TMG
Rectangles	Params	Pts or Params	Pts	Pts and Params	Pts
Triangle	Pts	Pts	Pts	Not Available*	Pts
Disc	Params	Pts or Params	Pts and Params	Pts and Params	Not Available
Cylinder	Params	Pts or Params	Pts and Params	Pts and Params	Not Available
Cone	Params	Pts or Params	Pts and Params	Pts and Params	Not Available
Quad	Pts	Pts or Params	Pts	Not Available*	Pts
Polygon	Pts	Not Available	Not Available	Pts	Not Available
Ellipse	Params	Not Available	Pts and Params	Pts and Params	Not Available
Paraboloid	Params	Pts or Params	Pts and Params	Pts and Params	Not Available
Sphere	Params	Pts or Params	Pts and Params	Pts and Params	Not Available
Box	Params	Pts or Params	Params	Not Available	Pts

Optical Properties and Nodalization

- Specular optical properties
  - Simulate the physical behavior of radiation
- Active sides – only active surfaces participate in radiation exchange
  - May be front, back or both sides of surface
  - Each radiating surface referenced by thermal node number
  - Each active side may be further subdivided into smaller sub-sufaces, which in turn may have different nodes
- Exceptions
  - Thermica and TRASYS do not allow different nodes on the front and back sides of a surface.
  - TRASYS requires MODPR command to implement different properties on opposite sides of surface
  - TRASYS does not perform specular radiation analysis
- Node Numbering of subdivide surface
  - Thermica and ESARAD follow (Starting Number, Increment) pattern
  - TSS full control over subdivision node numbers, single submodel
  - TRASYS uses the Correspondence Data block for node numbers

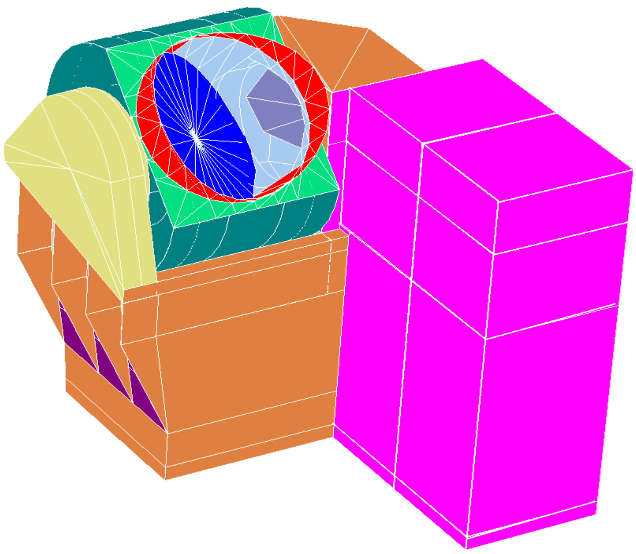
Examples

- Routines were developed for several Projects.
  - MetOp
  - SECCHI
  - EOS-Aura
  - EIS
- Each of the aforementioned projects has required partnership with a foreign company or organization and using software not commonly found in the United States
  - For each of these, Swales developed algorithms in Visual Basic to convert the model to or from the foreign software
  - These routines were written to be useful beyond the scope of the project for which they were developed
  - A number of inconsistencies between the European software (ESARAD and Thermica) and TSS were encountered and resolved. These are discussed with respect to the project to which they pertain

MetOp

MetOp is a European Meteorological satellite with seven instruments supplied by NOAA/NASA. The contract required all model deliveries be in ESARAD. Given the number of models and the predicted frequency of updates, it was considered worthwhile to automate this process.

- The detailed AMSU-A2 instrument is depicted to the right to show the relative complexity of the models.
- A routine was first developed to process a TSS file and transform an create the ESARAD points in the global coordinate system.
- A number of inconsistencies between ESARAD and TSS were solved to make the final conversion possible.



MetOp

- The table below lists some of the discrepancies encountered between the two formats.
- The routine automatically handles these inconsistencies with the exception of splitting an ellipse. (This option must be specified by the user.)

Feature	TSS	ESARAD	Workaround
Ellipse Entity Type	Yes	No	Polar Array of triangles
Non-sequential node numbering	Yes	No	Creation of separate entities
Non-uniform nodalization	Yes	No	Creation of separate entities
Optical Properties defined in same file as geometry	No	Yes	Create optics within output file
Variable length units	Yes	No	Convert all sizes to user defined units
Box Entity is one node	Yes	No	Assign node increment of zero
Node Label as surface property	No	Yes	Uses TSS entity name

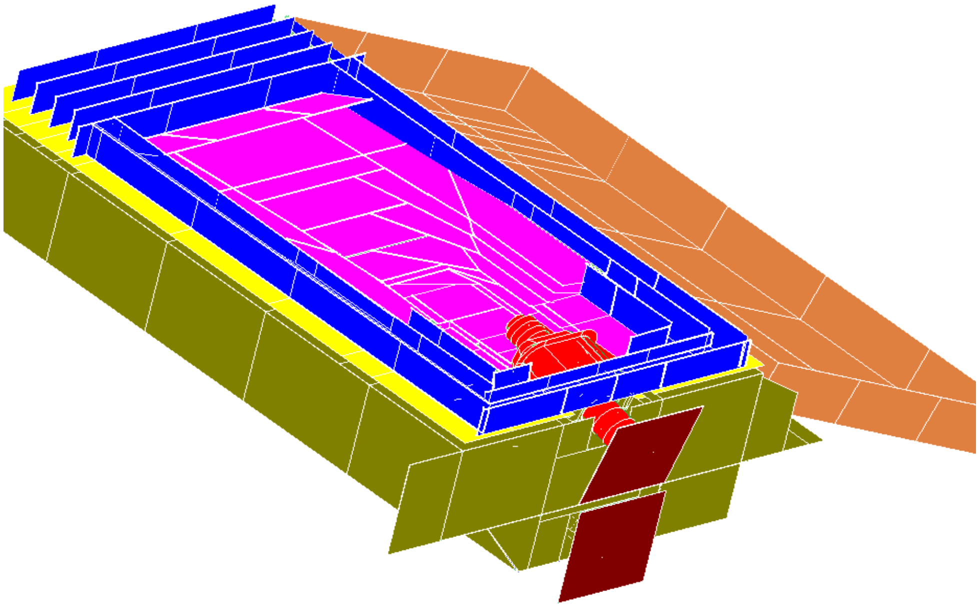
MetOp

- The ESARAD visualization tool was temporarily not functional.
  - A converter was written to convert the ESARAD spacecraft model to TSS in order to view the model.
  - Again, discrepancies were encountered and resolved.

Feature	ESARAD	TSS	Workaround
Cutting operations supported	Yes	No	Cutting entities created for reference
Copy operations supported	Yes	No	Create new entity by copying base entity
Update of entity properties after entity definition	Yes	No	Search through model tree and modify property
External submodels and/or files may be included in top level model	Yes	No	Insert entities from submodel at proper location
Extensive use of variables allowed	Yes	No	Storage of variables and values and evaluation of expressions

SECCHI and EOS-Aura

The SECCHI and EOS-Aura projects both had models submitted in Thermica that needed to be converted to TSS for further submission to the spacecraft contractor and internal use. The SECCHI model is depicted below.



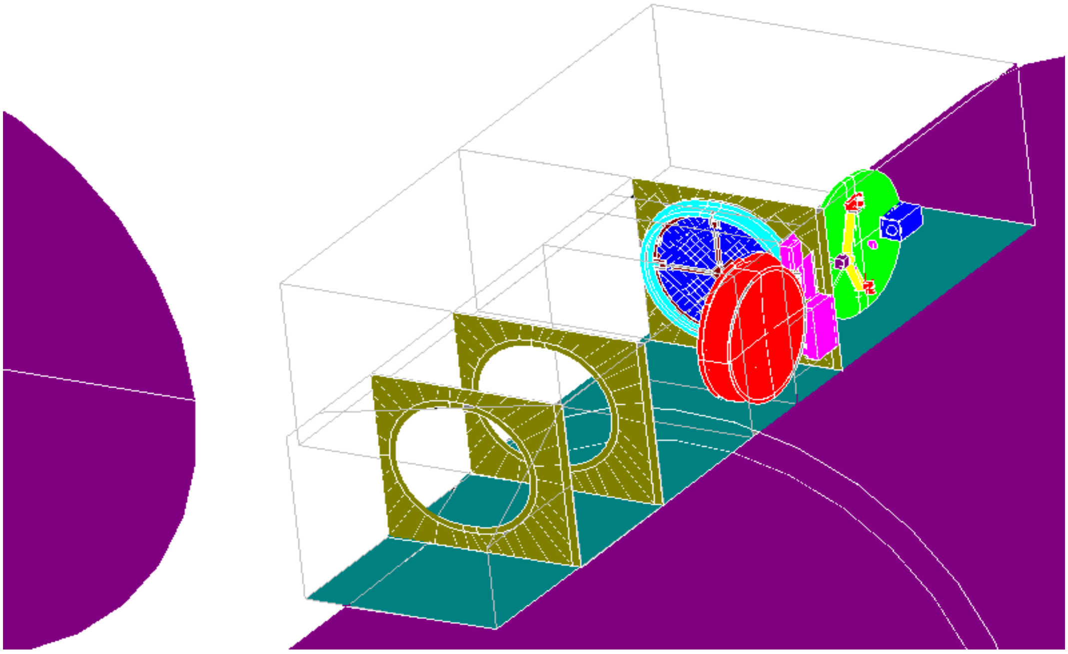
SECCHI and EOS-Aura

- **Discrepancies were again encountered and resolved.**
- **It was difficult to verify the conversion since Swales does not have a copy of Thermica and could not view the original model.**
- **A verified model was produced in conjunction with help from the US distributor of Thermica**

Feature	Thermica	TSS	Workaround
Non hierarchical order of entity input	Yes	No	Re-sort entities by object identifier
Multiple surfaces assigned to single entity	Yes	No	Create assembly containing surfaces
ANGLE1 allowed to be greater than ANGLE2 (i.e. Min > Max)	Yes	No	Add 360° to ANGLE2
Node numbering may be clockwise or counterclock-wise for revolved surfaces	Yes	No	Define node_ids appropriately (not yet implemented)
Extensive use of variables allowed	Yes	No	Storage of variables and values and evaluation of expressions
Optical Properties defined in geometry file	Yes & No	No	Both methods of property definition read and output to single optics file

EIS

The Clamshell Door model (depicted below) was created in TSS. Delivery of the model to the University of Birmingham was required in Thermica, requiring conversion from TSS to Thermica.



EIS

- This conversion presented a unique challenge
  - Swales does not have a method of previewing the converted file, since Thermica is not available at Swales
  - To verify the conversion, the converted Thermica file was reconverted and viewed in TSS to judge the conversion success
  - A valid Thermica model was produced after subsequent iterations with University of Birmingham. The discrepancies encountered are listed below

Feature	TSS	Thermica	Workaround
Non-sequential node numbering	Yes	No	Creation of separate entities
Non-uniform nodalization	Yes	No	Creation of separate entities
Optical Properties defined in same file as geometry	No	Yes & No	All properties written to geometry file
Variable length units	Yes	No	Convert all dimensions to user specified units
Double Sided surfaces (2 nodes)	Yes	No	Creation of two surfaces with small gap

Conclusions

- Less time spent converting models means quicker delivery of models to contractors.
- Future model conversions will benefit from the effort already expended to develop these routines.
- Time spent to develop the routines is judged to be less than estimated manual efforts.
- The necessity of model conversion is growing with the introduction of more analysis codes and more frequent international cooperative projects.
  - Smaller models could be converted manually with a minimum time impact.
  - Models will continue to grow in size and complexity making manual conversion impractical.
- Development of a new neutral format is unnecessary, since TSS provides all the flexibility needed to handle models from the majority of codes.

Future Plans

- These routines were recently developed and will continue to grow
- Eventually, any format could be loaded and stored as if it were a TSS model
- Data can be written to any desired output format
- These capabilities can also be broadened to develop utilities to interface with geometry models. Swales has already developed tools to:
  - Modify optical property names and remove unused properties
  - Output useful property information for each entity to a table
  - Add instrument specific prefixes to entity names to prevent conflicts when integrating multiple instruments
- These routines will continue to evolve in order to improve our efficiency and provide the best service to our customers

Appendix P: CIGAL2: An open source pre/post-processing tool for CORATHERM and other software activities

CIGAL2: an open source
pre/post-processing tool
for CORATHERM
and
other software activities

JP. Dudon
Alcatel

CIGAL2 : AN OPEN SOURCE PRE/POST-PROCESSING TOOL FOR CORATHERM & OTHER SOFTWARE ACTIVITIES

T. Basset, JP Dudon, JL Salançon

CONTENTS

- About CORATHERM Software
- A new pre-post processing : CIGAL2
- 3D Conduction Modeling

CONTEXT

CORATHERM in ASPI Cannes

- History
  - → Since 30 years
  - → Today : 40 users
- Used for
  - → Analysis and sizing tool for the Thermal Control: Platforms, payloads, scientific and Telecom programs
- Interface with main European software (to be improved)
- 2000 : ASPI decision for updating its software (30th ICES - 2000)
- 2002 : European Community for Standardization for Space
  - → Rather standard data exchange format than a standard tool for all
  - → Possibility of Marketing Conductive Module

CONTEXT

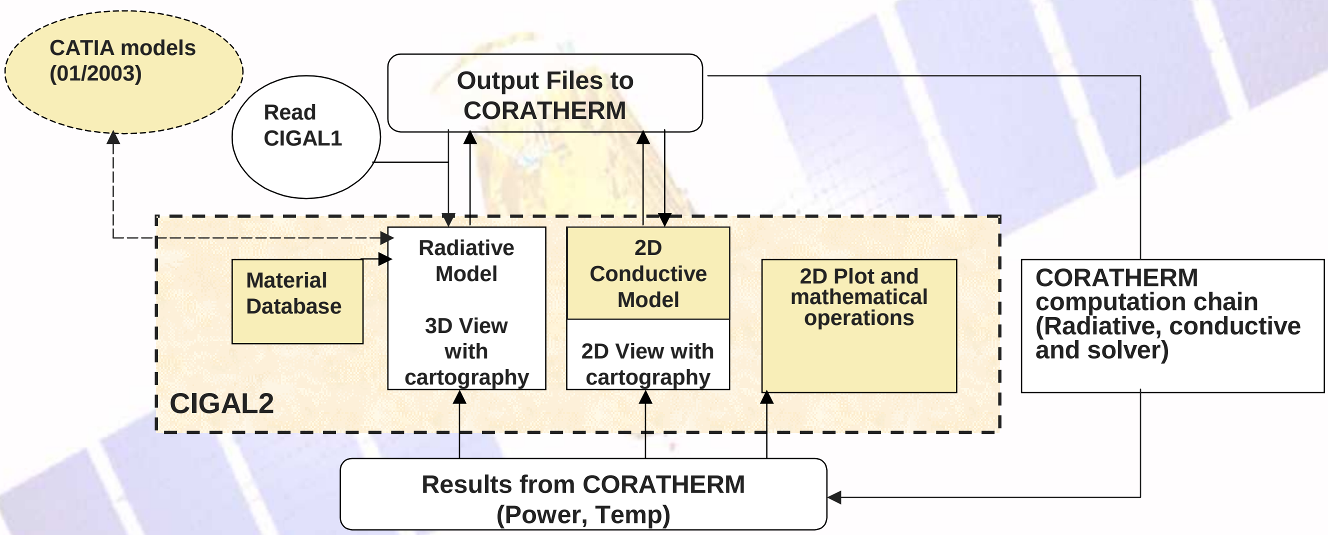
CORATHERM : Technical description

- Main parts :
  - →Radiative & 2D Conductive Modeling, Model condensing/Recalculation, Thermal solver
- Specific thermal modules :
  - → ...
  - → Calc. of thermal inputs for Thermo-Elastic analysis (*31st ICES-2001*)
  - → 3D Modeling of Thermal Conduction (in progress)
  - → LHP modeling at system level
- New Pre/Post Processing : CIGAL 2
  - → T0 development : 09/2001
  - → Currently used by Thermal analists (phase 1)

Why the Open Source Approach ?

- Built-in or dedicated solution ?
  - →Specific development fit better specific technical requirements
- Availability of source code
  - →Longevity and evolution of the software
  - →Facilitates porting issues
- The right to redistribute derived software
- Low cost for large utilization

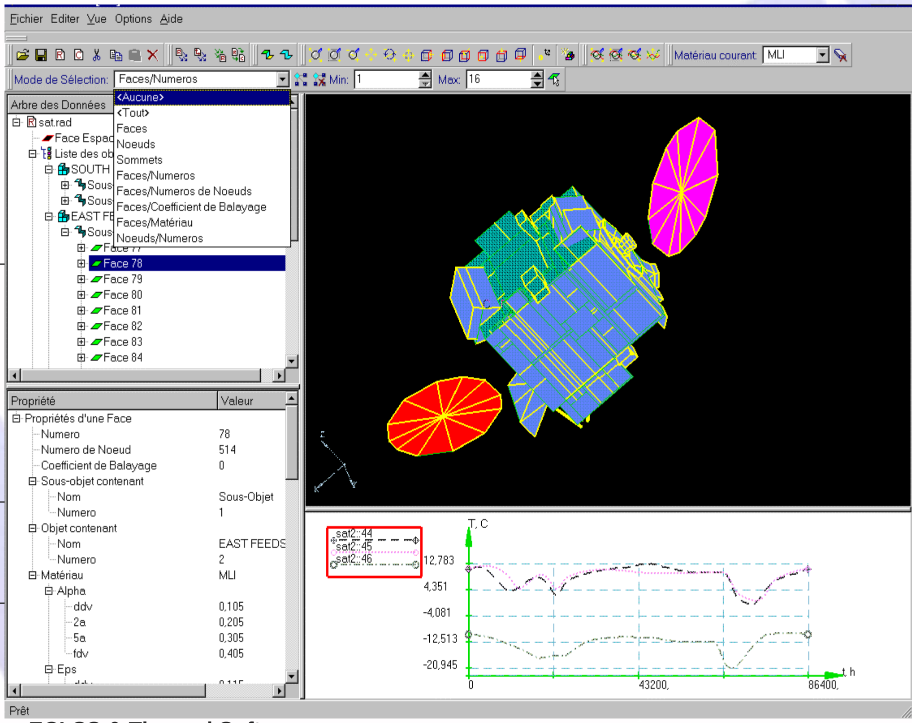
Software Architecture



ALCATEL SPACE

CIGAL2

User Graphical Interface



Model Data Tree

Properties Editing

3D interactive window (build, check and display)

2D plotting (post-process)

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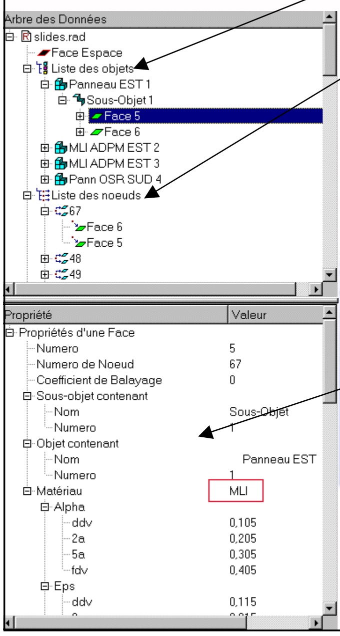
CIGAL2

♦ Radiative Model Processing

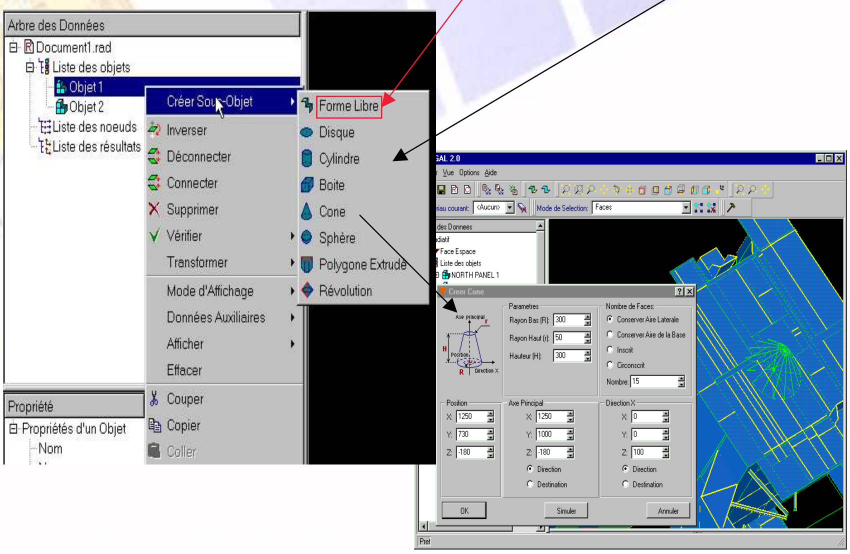
→1 CIGAL2 Radiative model = 1 cavity of the total model

Organisation { Geometry
Nodal breakdown

Numerous modeling possibilie (by facets or primitives)

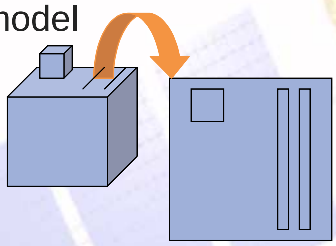


Facets Attributes

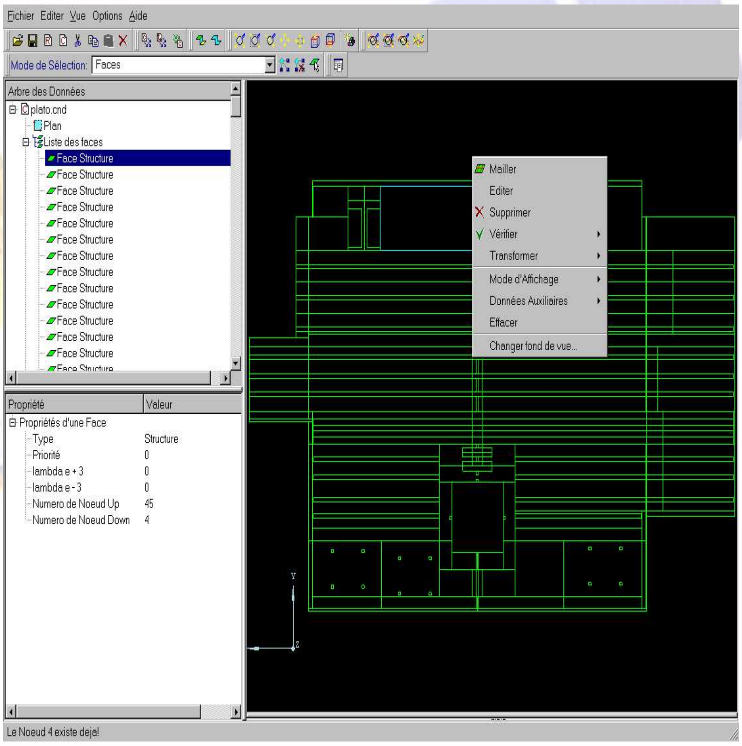


♦ 2D Conductive Model

- 1 conductive model = 1 panel
- Specially adapted to the 2D conductive module (DF method)
- Possibility to create directly a conductive model from a part of radiative model



- Automatic generation of input data file for CORATHERM

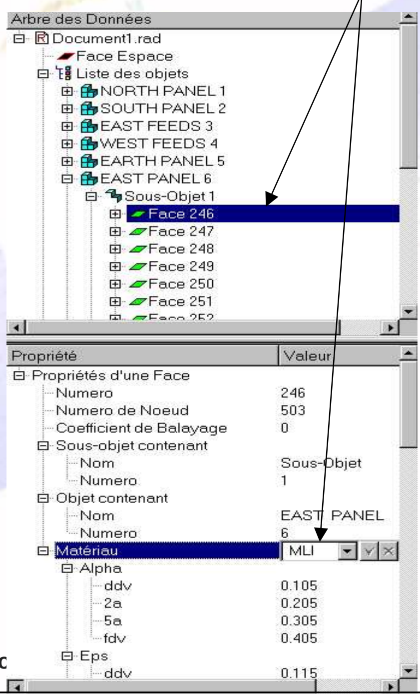


♦ Material Database

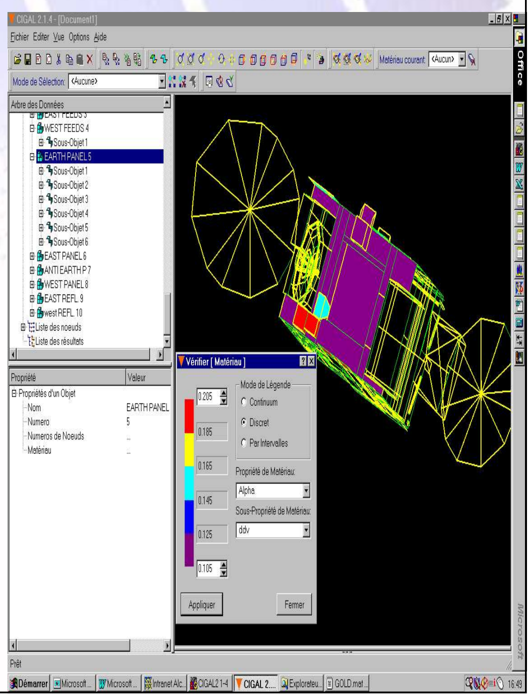
- Set of material datafile (text format)

```
NOM:NIDA
#Nid d'abeilles
# Dans cet exemple, Alpha n'est pas defini en ddv
Alpha  :  Absortivite
Alpha.2a  : 0.1
Alpha.5a  : 0.2
Alpha.ddv : 0.205
Eps  :  Emissivite
Eps.ddv : 0.2
Eps.2a  : 0.21
Eps.5a  : 0.22
Eps.fdv : 0.23
Rho  :  Reflexivite
Rho-Vis-Dif   :  Reflexivite Visible Diffuse
Rho-Vis-Dif.ddv : 0.3
Rho-Vis-Dif.2a  : 0.31
Rho-Vis-Dif.5a  : 0.32
Rho-Vis-Dif.fdv : 0.33
Rho-Vis-Spec  :  Reflexivite Visible Speculaire
Rho-Vis-Spec.ddv : 0.4
Rho-Vis-Spec.2a  : 0.41
Rho-Vis-Spec.5a  : 0.42
Rho-Vis-Spec.fdv : 0.43
Rho-IR-Dif    :  Reflexivite Infrarouge Diffuse
Rho-IR-Dif.ddv : 0.5
Rho-IR-Dif.2a  : 0.51
Rho-IR-Dif.5a  : 0.52
Rho-IR-Dif.fdv : 0.53
Rho-IR-Spec   :  Reflexivite Infrarouge Speculaire
Rho-IR-Spec.ddv : 0.6
Rho-IR-Spec.2a  : 0.61
Rho-IR-Spec.5a  : 0.62
Rho-IR-Spec.fdv : 0.63
Tau  :  Transmissivite
Tau-Vis-Dif   :  Transmissivite Visible Diffuse
Tau-Vis-Dif.ddv : 0.7
```

- Affectation of the materials to the model



- Numerical & Graphical Checking of properties



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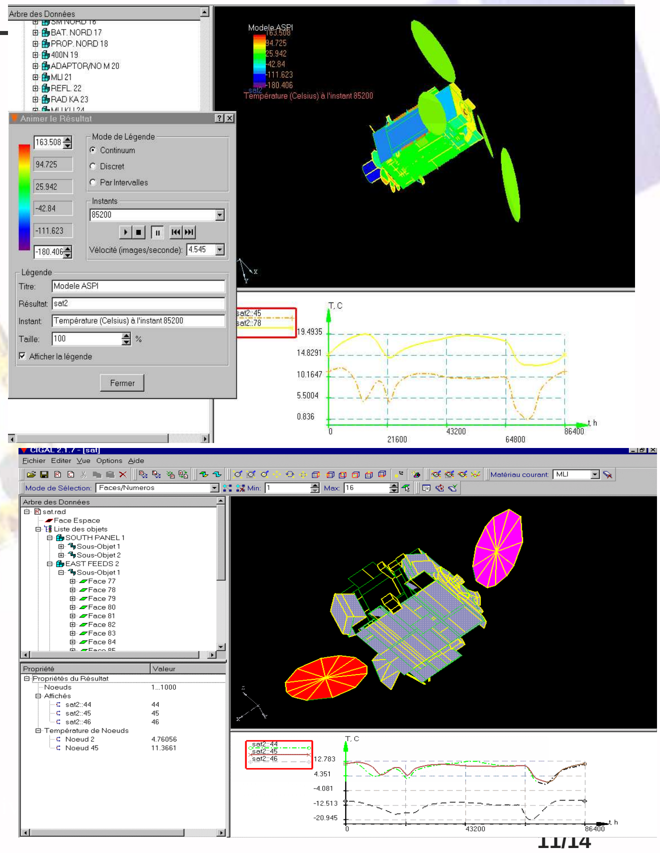
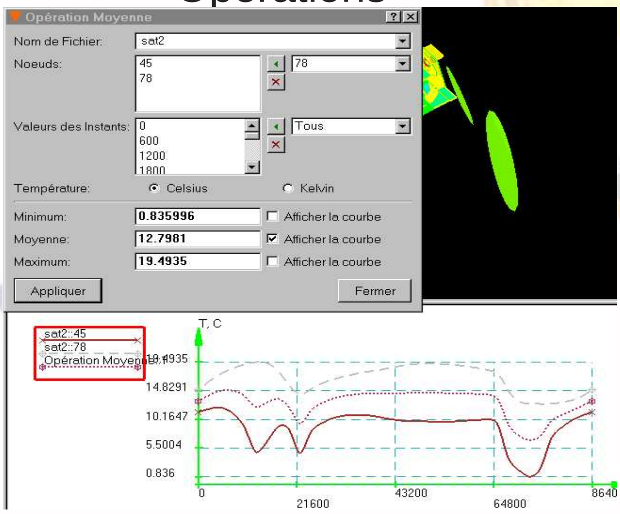
CIGAL2

- Post Process
  - → 3D Animation
  - → 2D plot
  - → Math. Operations





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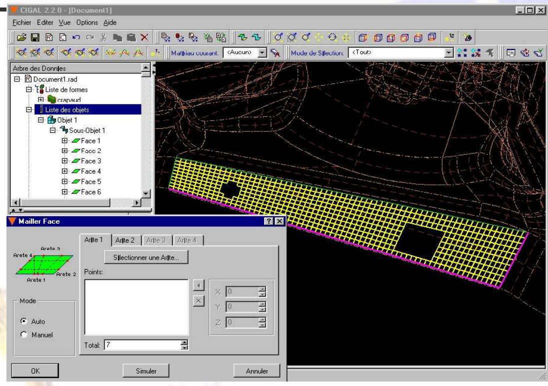
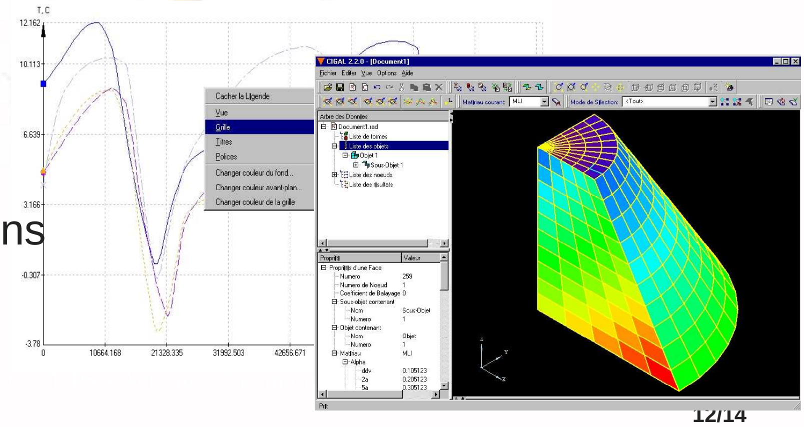
CIGAL2

CIGAL2/Phase 2

- Import of CAD files (STEP AP203/214 and IGES
  - →Under development (deliverable in 01/2003)



- New possibilities
  - → Undo/Redo
  - → Partial revolution
  - → Excel like functions
  - → ….



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CIGAL2

Prospects Round about CIGAL2

- Satisfaction of users

- A base for future developments (ECSS and ASP)
  - → 3D modeling of Thermal Conduction (in progress)
  - → STEP-TAS interface (2003)
  - → Orbital visualisation module

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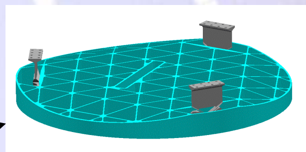
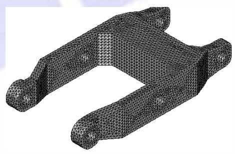
3D Conduction

About 3D conduction modeling activities

- Current progress
  - → User needs assessment
    - Lot of time lost with hand-made conductive
    - 2 types of solutions required :
      - "2.5 D" : Adaptation of EQUIVALE
      - "Real 3D" : Pure conduction
  - → EF methods are promising





- ASP's in-house development
  - → On the base of a tool developed in Valence (Micro-electronics)
  - → 3D Thermal analysis software
    - Conduction, Radiation, Convection
    - FE, FD and lumped parameter methods
    - Integrated pre/post processing for Cartesian meshing + interfaces
    - Model condensing and re-calculation

Appendix Q: TMG: New Technologies and Modelling Approaches

TMG:
New Technologies
and
Modelling Approaches

C. Ruel
Maya HTT

TMG: New Technologies and Modeling Approaches

Sixteenth European Thermal & ECLS Software Workshop

22-23 October 2002

Introduction to TMG

Comprehensive thermal simulation software package

Integrated with I-DEAS and FEMAP

- advanced FE modeling packages

Finite volume method

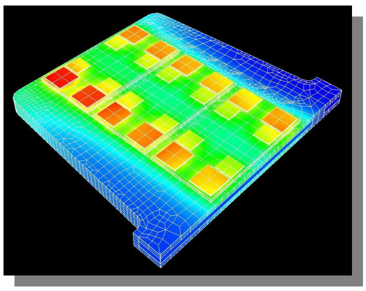
- accurate, efficient

Complete, integrated radiation simulation

- radiosity, ray-tracing, orbital heating

Fluid flow simulation

- comprehensive CFD, duct flow capabilities
- free and forced convection



State-of-the-art solvers

- powerful iterative solver (bi-conjugate gradient stabilized technique)
- implicit, explicit transient integration scheme

Open, modular architecture

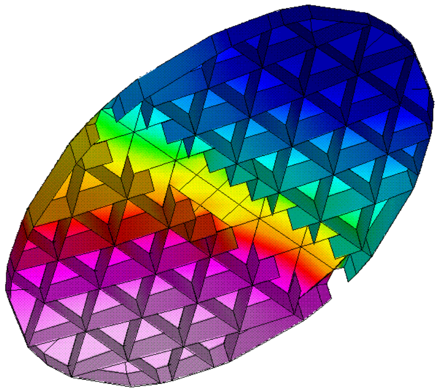
- fully documented
- user subroutines

Modeling technologies

Geometry-based modeling
- consistent mesh for conduction, radiation
- extensive CAD abstraction tools
- associativity, assemblies

Meshing
- free, mapped, manual

Conduction
- finite volume method
- accurately handles arbitrary element shapes
- orthotropic materials, multilayer shells
- compatible with finite difference solvers (SINDA / ESATAN)



Thermal couplings
- modeling assemblies
- enables geometry abstraction
- sliding contact

Graphical post-processing, results visualization
- model validation and correlation

Conduction formulation

Finite volume formulation
- elements used directly as control volumes
- local, global conservation of energy
- yields accurate conductive conductances for arbitrary element shapes
- retains “physicality” of finite difference approach

Calculation points (network “nodes”) established at the boundaries of the element and the centroid

Capacitance, surface heat transfer (radiation, convection) “lumped” at the centroidal point

Efficient handling of temperature-dependent thermal conductivity
- all terms are associated with a single element

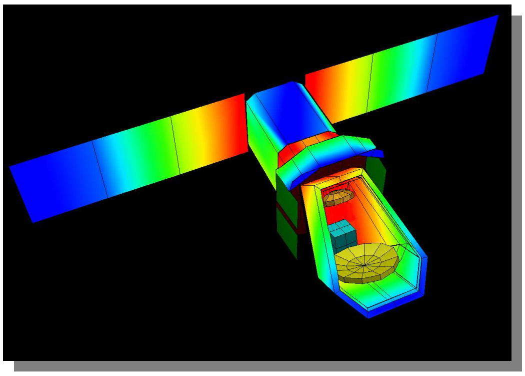
Compatible with SINDA / ESATAN
- TMG’s solution matrix can be solved using SINDA / ESATAN

Supports direct entry or modification of conductances and capacitances
- “non-geometric” modeling

Radiation

TMG radiation simulation:

- full modeling of radiative interchange
- orbital environmental heating
- arbitrary radiative sources
- diffuse/specular/transmissive surfaces
- articulating, spinning assemblies
- angle-dependent specularity, transmissivity
- temperature-dependent emissivity
- refraction



Solution technology:

view factors using hemicube or analytical methods
deterministic ray-tracing for specular reflections (two-pass method)
iterative correction of view factors to extinguish residual
radiosity methods for radiative interchange calculations
conjugate gradient solver technology to handle very large models

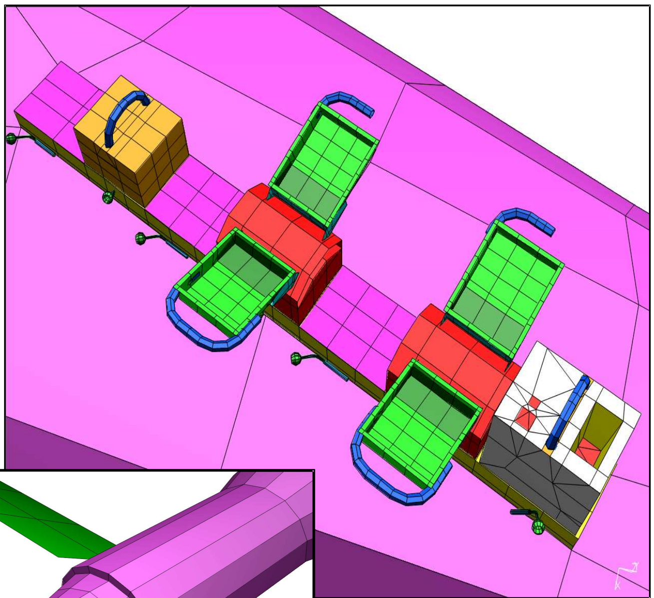
View factor calculation

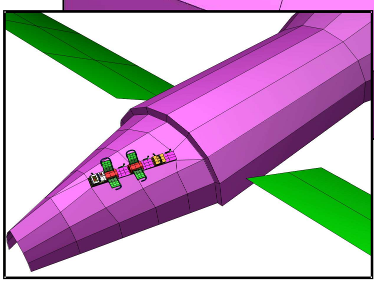
Hemi-cube algorithm

- uses graphics hardware
- implementation based on OGL
- very fast, especially for large models
- error detection and correction

Analytical algorithm

- exact contour integral technique for unshadowed surface pairs
- Nusselt sphere method for obstructed views
- control over subdivision, including error-based scheme
- shadowing surface algorithm minimizes shadowing checks





Ray tracing

Two-pass method:
- specular reflections and transmissions are ray traced
- view factor matrix is adjusted

Ray distribution is deterministic
- based on view factors to specular, transmissive elements
- elements are subdivided, rays launched between sub-elements
- user controls subdivision level (ray density)
- ray density can be proportional to view factor magnitude
- rays traced until extinguished

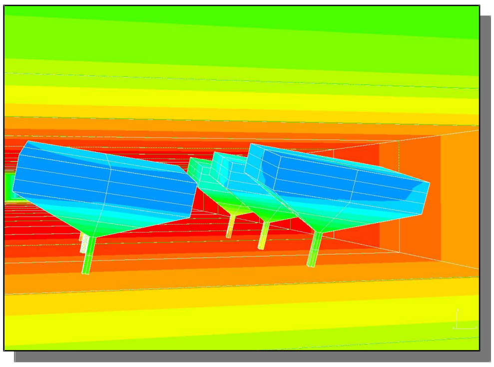
Accurate and efficient solution of large models
- generally much less sensitive to ray density, sampling issues than Monte Carlo
- exploits efficient solution of radiosity equations using iterative solvers

Supports curved surfaces
- parabolic elements capture surface curvature
- enables accurate modeling of focussing effects (e.g. parabolic reflectors)

Directional surface properties
- specular reflectivity, transmissivity versus angle, direction of incidence

Radiative exchange matrix

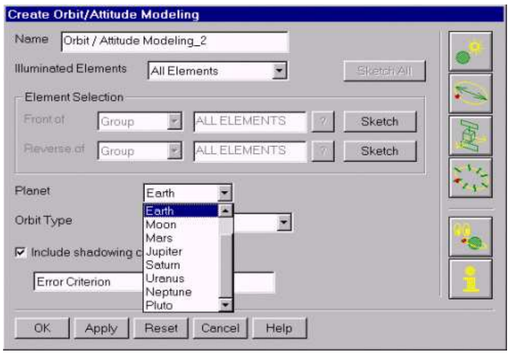
Iterative adjustment algorithm to extinguish residual view factors
- handles internal or external enclosures
- preferentially corrects shadowed view factors
- effective correction of view factors to space

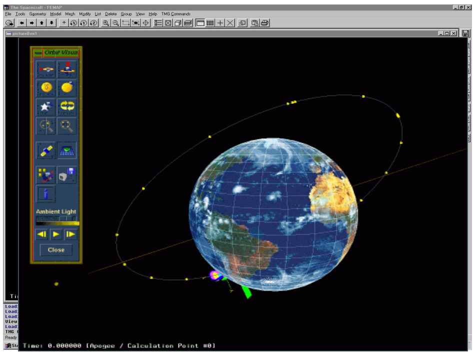


Gebhardt's formulation
- yields element-to-element conductance matrix
- inefficient for large models

Oppenheim's method (radiosity)
- exploits advanced iterative solver
- bypasses matrix inversion
- generally yields smaller radiation matrix
- handles temperature-dependent emissivities accurately, efficiently
- have observed order-of-magnitude reductions in solution time versus Gebhardt's
- very efficient for articulating models

Orbit and attitude modeling





Orbital modeling/heating for spacecraft

- select planet, orbit type
- planet and sun data is pre-loaded
- solar flux calculated from date
- vector-based attitude modeling
- arbitrary rotations, maneuvers
- control over orbital calculation points
- option to enter sun, earth vectors
- orbit chaining

Orbit Visualizer

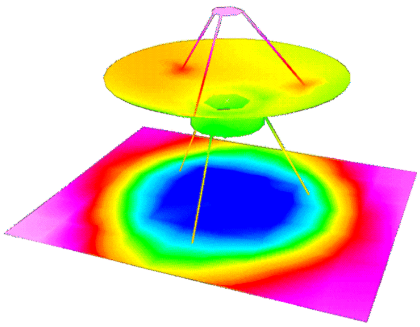
- Animated view of model in orbit
- Dynamically rotate while animating
- Viewer updates dynamically with parameter changes in forms

MAYA

Orbital heating

Computes orbital environmental heat loads

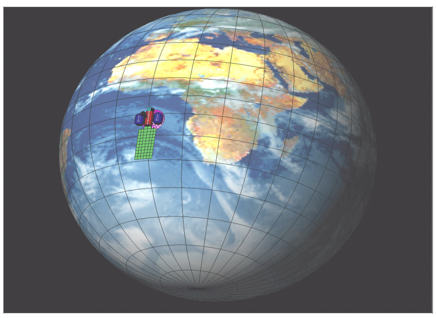
- direct solar, albedo, planet IR
- computes view factors to environmental sources
- eclipses modeled automatically
- ray tracing of specular reflections, transmissions of collimated solar
- radiosity formulation of radiative exchange equations (extended Oppenheim's method)
- efficient solution using iterative conjugate gradient solver



Heat loads automatically loaded for solver

Articulating spacecraft

- efficient algorithms to recompute view factors
- visualize results on displaced geometry



Spinning spacecraft

- heat flux averaging

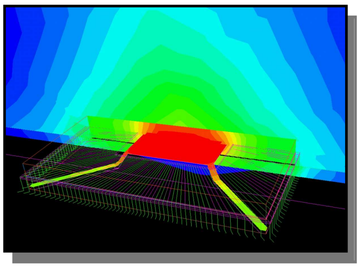
Orbital averaged heat loads

MAYA

Thermal solver technology

Steady state: conjugate gradient solver

- powerful iterative solver (bi-conjugate gradient stabilized technique)
- pre-conditioning matrix (ILU factorization)
- Newton-Raphson method for non-linear terms
- very high performance for large, ill-conditioned systems
- handles negative terms



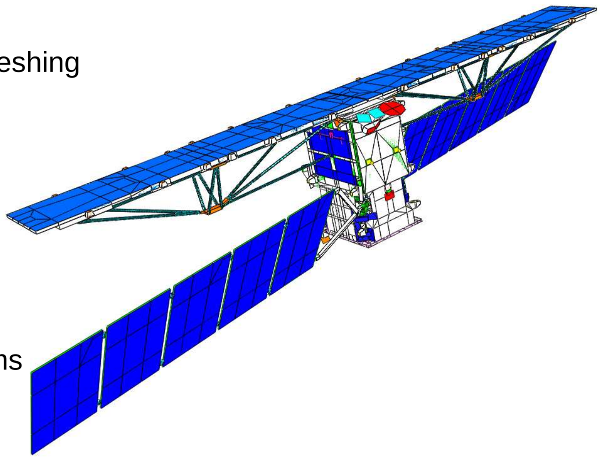
Transient solver

- explicit schemes: forward, exponential forward
- implicit methods: arbitrary degree of implicitness
- also exploit CG solver

Radiation for large models

Strong trend towards larger models for spacecraft thermal analysis

- modern finite element modeling tools enable meshing of complex systems
- greater processing power available
- geometric fidelity
- minimize discretization errors



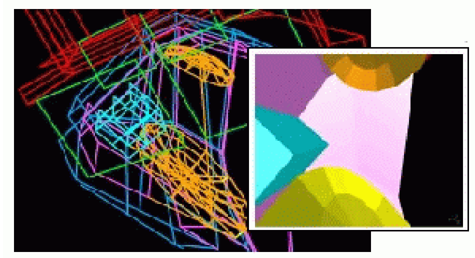
Challenges:

- computing the radiative exchange terms
- storing, manipulating the terms
- solving the model
- post-processing and diagnostics

Radiation for large models

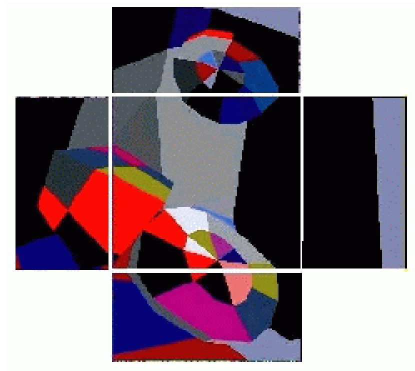
Hemicube method for view factor calculation

- enabling technology for large FE-based radiation models
- calculation time nearly linear with element count
- uses OGL-based rendering - exploits high performance graphics hardware



How it works:

- pixelized half-cube constructed around radiating element
- all other radiating elements are graphically projects onto the faces of the cube, using OGL
- each pixel is associated with a precomputed view factor
- Algorithm collects rendering data, and computes view factors



Accuracy:

- view factor resolution limited by pixel size: user controlled tradeoff between accuracy and calculation time
- algorithm detects closely-spaced elements, and performs multiple renderings from distributed positions on the emitter
- excellent overall accuracy observed for all classes of models

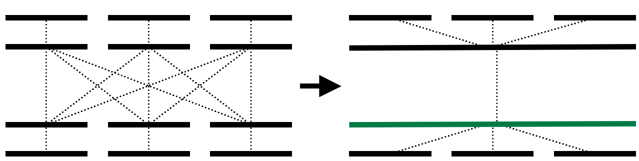
Radiation for large models

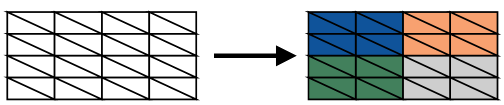
“Patching” algorithm

- densely meshed models can yield a very large number of radiative terms (up to n^2)
- conjugate gradient solver technology can effectively handle very large models, but:
  - memory requirements and disk space can become a problem
  - transient model solve time can still be an issue
- A new algorithm was developed in TMG to which exploits the radiosity formulation to condense the radiative exchange matrix

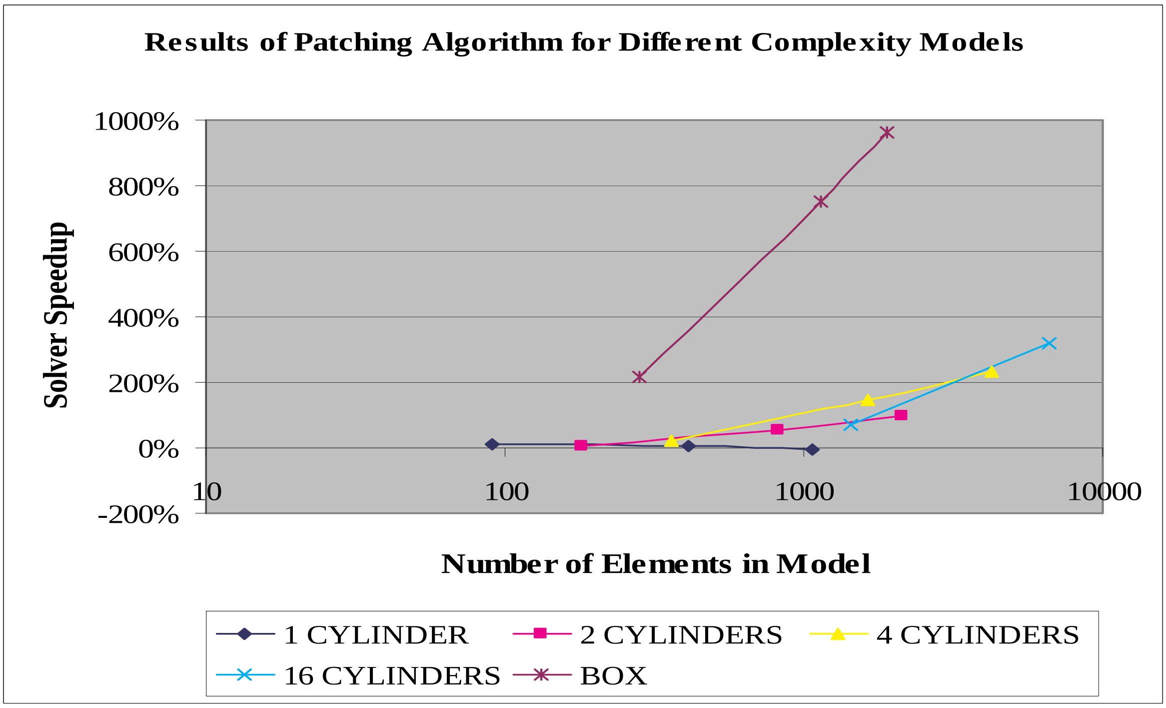
How it works:

- automatically identifies “patches” - sets of adjacent elements with identical thermo-optical properties
- merges the Oppenheim nodes (radiosity potential) for all elements in a patch
- includes new terms to correct for false diffusion between the patch elements
- with the default settings, generally reduces the radiation matrix by an order of magnitude



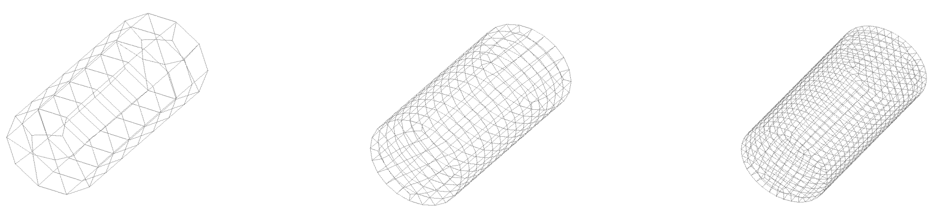


Patching algorithm



Patching algorithm

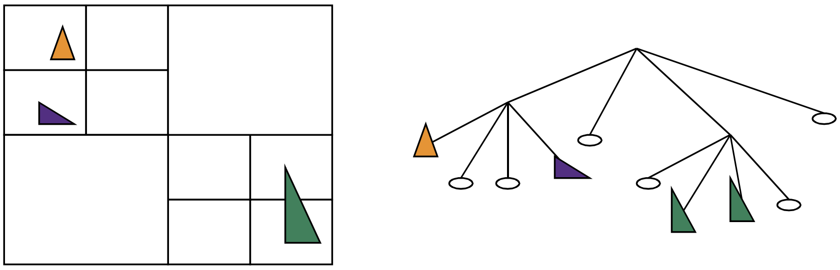
Model	# elements	patched ?	Max. Temp. Error (deg.C)
1 cylinder	1064	no	reference
1 cylinder	1064	yes	0.007
1 cylinder	412	no	1.44
1 cylinder	412	yes	1.49
1 cylinder	90	no	5.780
1 cylinder	90	yes	5.88



Radiation for large models

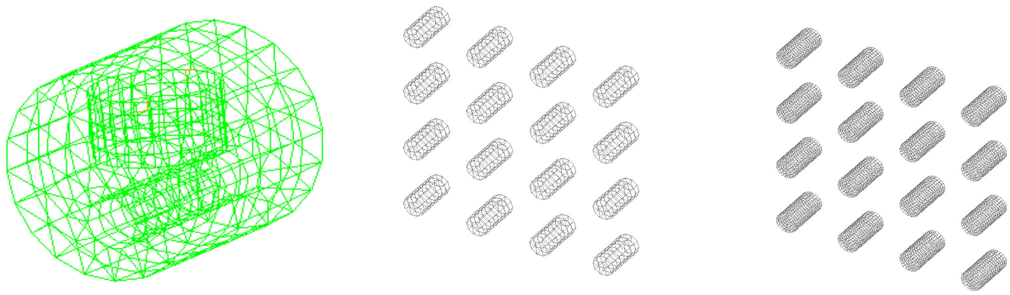
Advanced data structures

- designed to accelerate ray tracing procedure for large models
- Octree data structure for spatial sorting and searching
- Pluecker coordinates:
  - six dimensional coordinates for representing line segments in space
  - test of ray-polygon intersection requires only a few operations with Pluecker coordinates
- View factor storage/retrieval data structure
  - efficient scheme for tallying up the view factors as the ray tracing proceeds



Advanced data structures

New ray-tracing engine designed based on these data structures



Model	# of Elements	Time without advanced data structures	Time with advanced data structures	Speedup
3 Cylinders	834	29.6 minutes	17.6 minutes	1.68
16 Cylinders	1446	2.06 hours	15 minutes	8.24
16 Cylinders	6598	17.2 hours	8.3 hours	2.07

Thermal model reduction

Computing heat flow between groups

- it is impractical to directly incorporate large, high-fidelity thermal models into a system-level model - model reduction technology is necessary (like Craig-Bampton method for structures)
- to provide engineering insight into large thermal models, it is necessary to enable users to evaluate heat flows between model segments (not just elements)
- Both of these requirements are addressed in TMG using an algorithm to compute heat flows between arbitrary groups of elements

How it works

- For radiative heat flows:
  - Set temperature of all secondary elements to 0K (i.e. no emission)
  - solve the full matrix to compute net heat radiative flow to all elements (exploits CG solver).
  - collect results for secondary group
- conductive heat flows extracted directly
- net conductances between groups computed from heat flows and temperatures
- For thermal model reduction, model is simply partitioned into non-overlapping groups.

Thermal Optical Mechanical Testbed

Proposed designs for space-based interferometers require optical element stability at picometer level

- corresponds to temperature disturbances at mK level
- thermally induced deformations are typically the major barrier to diffraction-limited performance

Verification by ground test of end-to-end optical performance is not practical

- analysis will play a major role in instrument validation

Project undertaken by Lockheed Martin ATC in collaboration with JPL:

- validate specific design requirements of the NASA/JPL Space Interferometry Mission (SIM)
- validate thermal-optical-mechanical models at disturbance levels for which thermally-induced wavefront errors are estimated to be significant for the SIM instrument: temporal changes in through-thickness gradient to the order of ± 1 mK

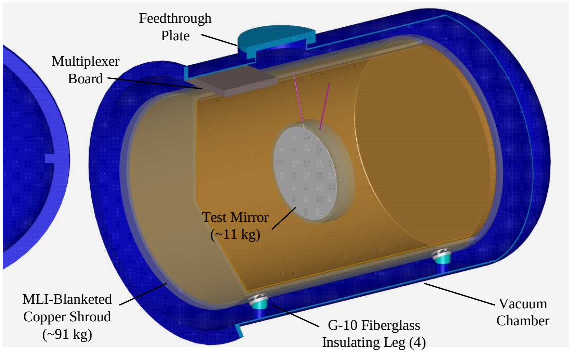
Test configuration

Cylindrical copper shroud mounted on four fiberglass supports inside the vacuum chamber

Shroud covered with 20 layer blanket, painted black on interior

Calibrated miniature Platinum Resistance Thermometers used for measurement

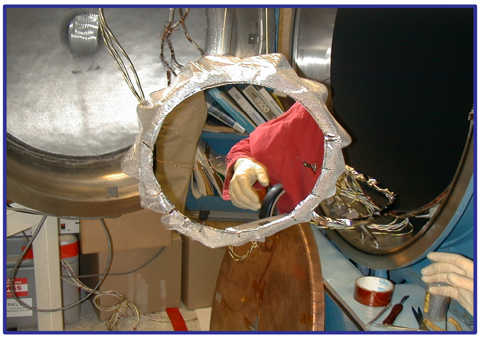
- high accuracy readout system: ± 1 mK relative accuracy following calibration

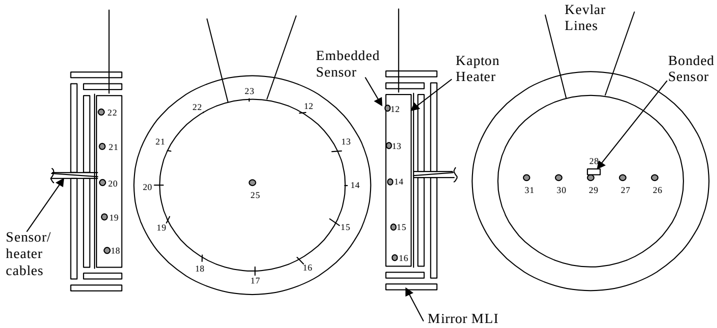


Test article

Test Article was pyrex plano mirror:

- 33.5 cm by 5 cm thick
- suspended in shroud via kevlar twine
- kapton heater bonded on back surface
- offset aluminum heater plate for radiative heating
- 40 layer MLI on sides and back
- instrumented with 18 PRT’s



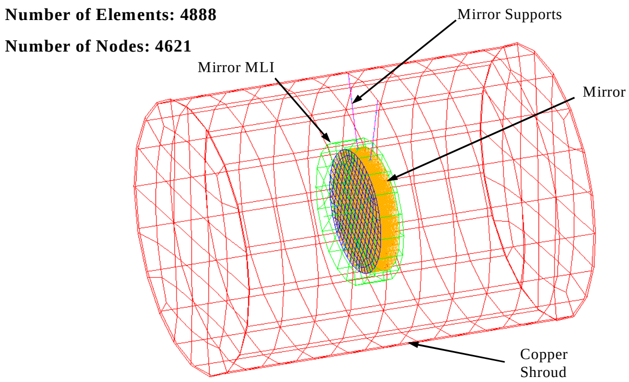


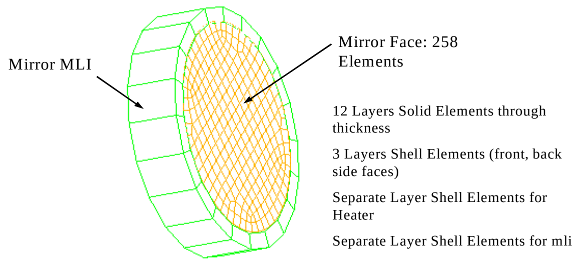
Thermal model

Numerical thermal model constructed using I-DEAS TMG

Boundary conditions:

- Fixed, constant shroud temperature
- Fixed temperature at Kevlar line ends (same as shroud)
- Fixed temperature at cable bundle end (same as shroud)
- Fixed heat load on heater or heater plate



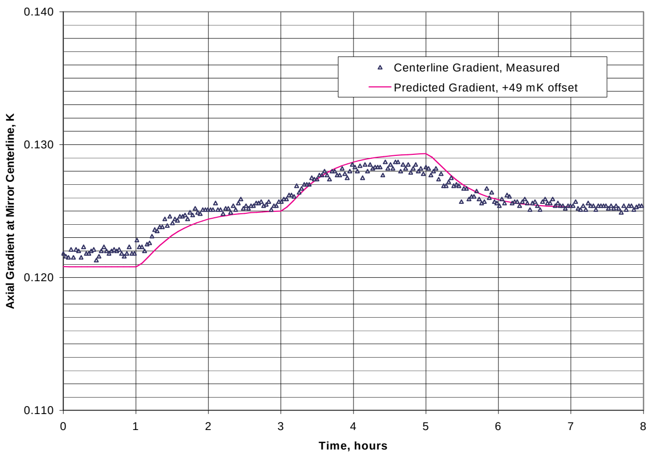


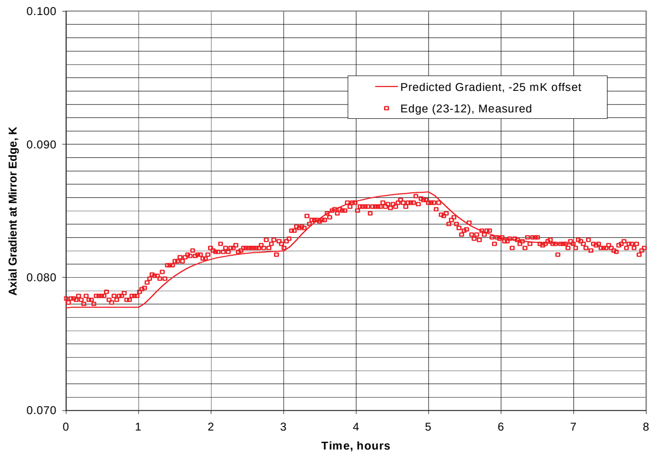
Results comparison

Transient behaviour of the predicted gradients was found to match the measured values very well

- agreement of approximately ±1 mK

Absolute gradients matched to within 25-50 mK

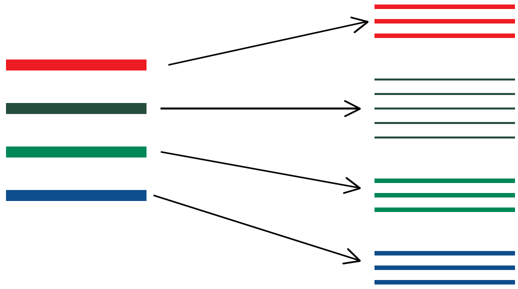




TPS modeling

Multilayer shell elements

- multiple layers of TPS represented by single shell element
- user specifies number of layers; TMG subdivides the element at solve time
- conductive couplings are automatically computed between layers, based on thickness and conductivity
- Thermal Couplings connected to top or bottom layer according to geometry
- supports orthotropic and temperature dependent material properties
- post-processing of layer results

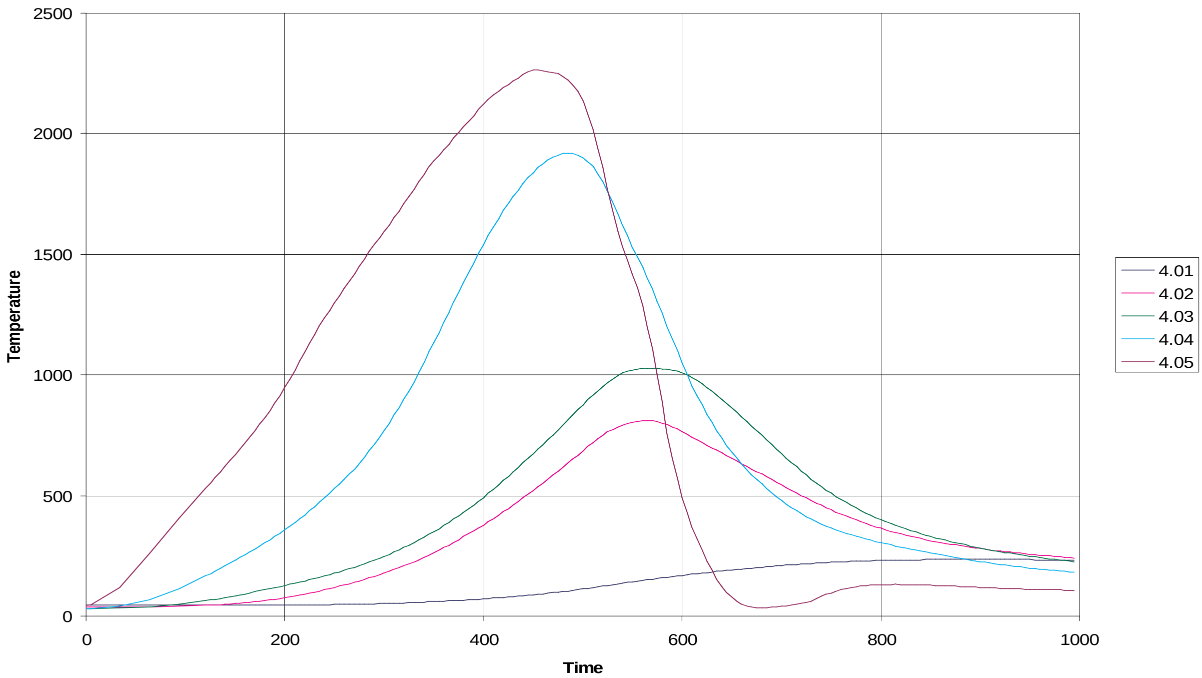


shells in model

TPS layers

MAYA

Temperature Profile Through TPS



MAYA

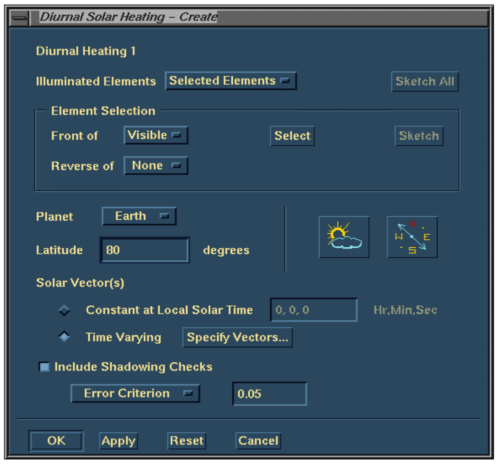
Other new TMG technology

Diurnal Solar Heating

- computes solar radiative heating on planet surface
- accounts for atmospheric attenuation
- computes solar flux from time/date and planet location, ground surface reflectance, diffuse sky radiation and cloud cover and altitude
- solar vectors can be fixed or time varying

Sliding Contact

- TMG's Thermal Couplings feature now supports articulation
- time-dependent conductances will be computed based on the translation or rotation of the elements with respect to each other

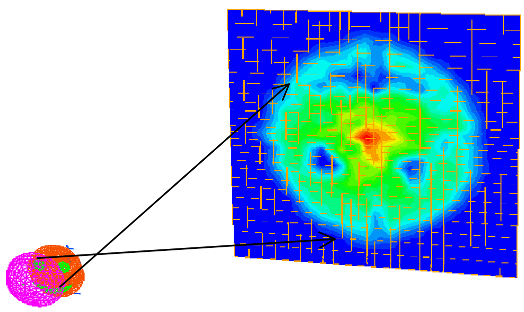


Other new TMG technology

TMG now supports modeling of refraction through transparent materials

Explicit earth model

- option to use a meshed model of the planet for computing orbital fluxes
- provides more accurate calculation of planetary heat fluxes through narrow apertures
- element density under user control
- element distribution on the planet is optimised



Binary files

- Option to store view factors, conductances in binary format
- Reduces disk space, solution time (up to 2X)
- Utility proved to convert back to ascii

Primitives-based Modeling

Complementary modeling system based on shape primitives
- ESARAD/THERMICA approach
- creates element-based models for TMG
- can be exported as true primitives
- enables the import of primitives-based models

Parameter and point methods
- Distances and points can be picked from graphics or keyed in

Properties: color, material, thickness

HTML online help
- Detailed bitmap image

GUI is driven from ASCII file
- can easily be modified by user to support new type of primitives

Tools to move and rotate primitives

Primitives-based Modeling

Import / Export
- **Tss**
- **Esarad**
- **Thermica**

Includes all material properties

Testing:
- **Component and large (7,000 primitives) system models have been imported / exported.**

Thermal results reporter

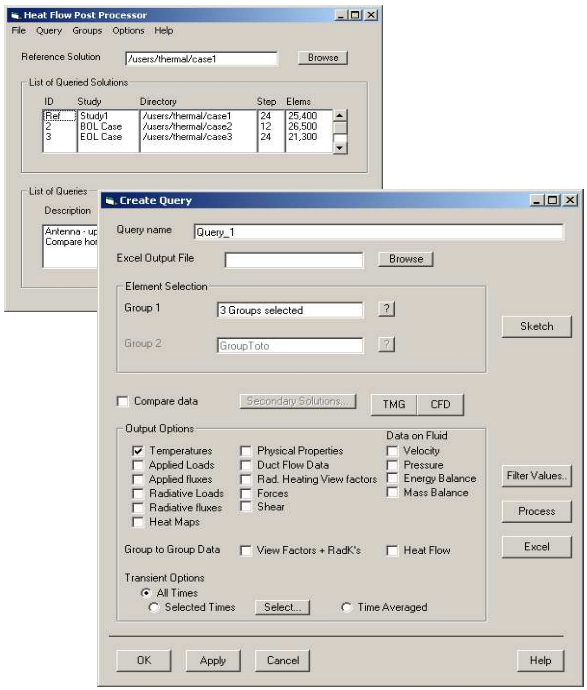
New capability, under development

Will let users query the solution results for detailed data

- steady state
- transient
- compare solutions
- time history
- orbital fluxes and view factors
- group to group heat flows
- heat maps

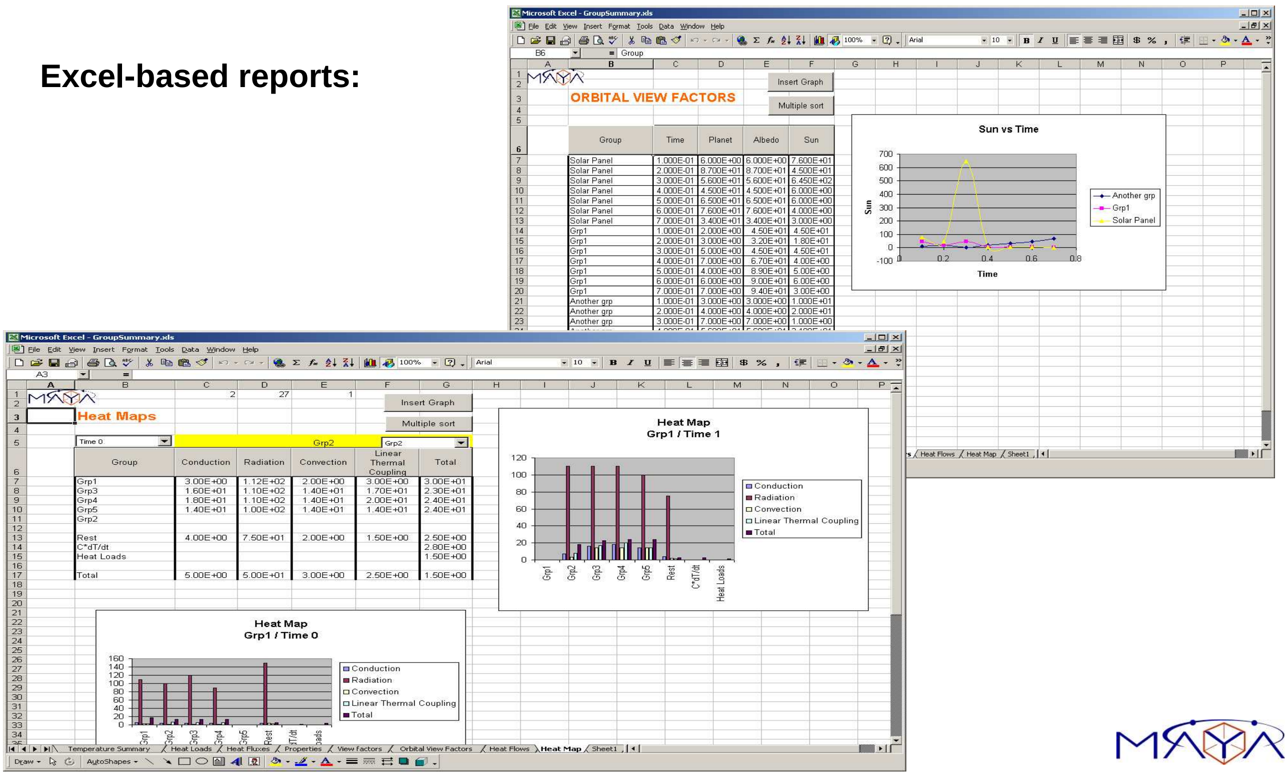
Data is automatically loaded into Excel spreadsheets

- macros to plot and sort



Thermal results reporter

Excel-based reports:



MAYA

Appendix R: SYSTEMA/THERMICA version 4: Overview of the new capabilities

SYSTEMA/THERMICA
version 4:
Overview of the
new capabilities

M. Jacquiau
Astrium SAS

SYSTEMA / THERMICA version 4
Overview of the new capabilities

Prepared by Marc Jacquiau, Astrium SAS

16th European Workshop on Thermal and ECLS Software, 22-23 October 2002

astrium

SYSTEMA / THERMICA current status (1/3)

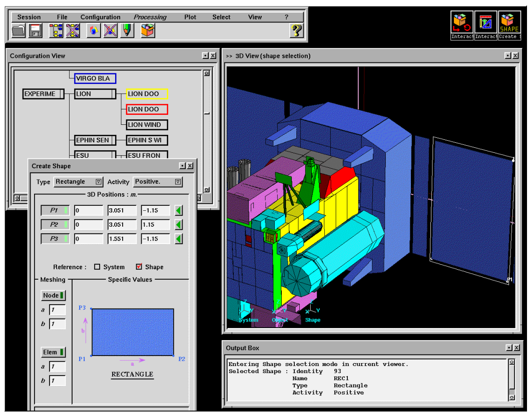
- **SYSTEMA is a common framework for several spacecraft applications :**

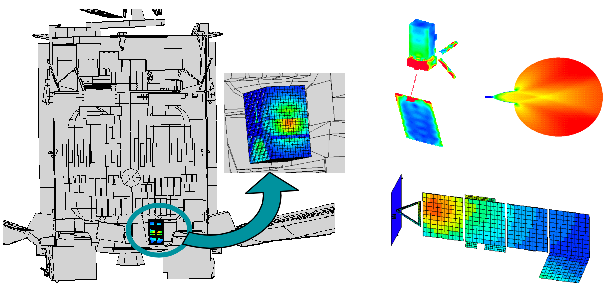
SYSTEMA

FRAMEWORK
- Computing tech.
- Input/Ouput
- User Interface
- Display 2D 3D
- Modeler 3D
- Pre-processing
- Post-processing
- Ray Tracing
- Schematic

APPLICATIONS
- Orbit
- Pointing
- Mass
- Radiation dose
- Debris
- Oxygen atom
- Plume
- Elect. propulsion
- Chem.Propulsion
- Outgassing
- Power
- Antenna patterns
- Radiative
- Conduction
- Link to solvers

THERMICA





SYSTEMA / THERMICA current status (2/3)

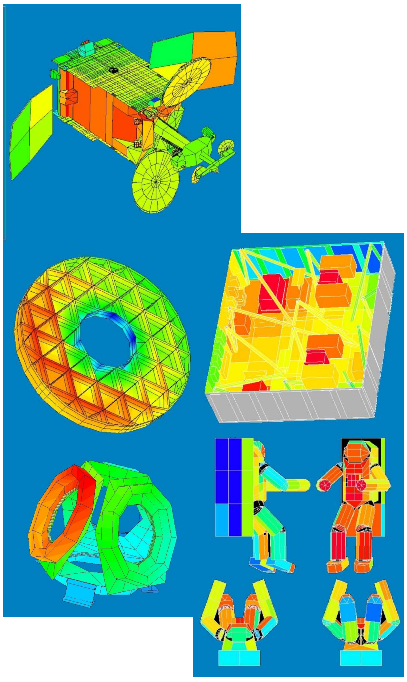
- **THERMICA is an integrated thermal chain for the design of spacecraft thermal control :**
  - In feasibility studies
  - For technological choices (passive or active controls)
  - During correlation with test predictions

- **Allows thermal considerations to have an impact on the system design, mission planning and the concept of operations**

- **THERMICA computes :**
  - Thermal radiation exchanges with space and between surfaces
  - External fluxes : Sun, Planet albedo, Planet IR emission

  Monte Carlo Ray Tracing
  - Thermal conduction in structures
  - Temperatures by means of other commercial packages (Esatan, Sinda/G)

- **THERMICA takes advantage of <u>common developments</u> with the other applications : framework + mission tools**
  - Reduced cost for users
  - Better synergy for evolutions



SYSTEMA / THERMICA current status (3/3)

- **Our development philosophy :**
  - To be close to users (internal & external) to fit their needs
    - Users meetings
    - Analysis also performed by software development team
  - To use up-to-date computing technologies : less Fortran, more C/C++, use of OSS
  - To perform enhancements without increasing maintenance cost for users
    - The goal for Astrium isn't to make profit with software but to improve engineering tools

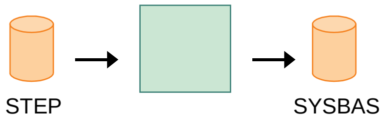
- **User feed-back permits to identify the development priorities**
  - Model generation :
    - Requirement for CAD-like tools
    - Interface with CAD tools
    - Combination of sub-models
  - Thermal model exchange
  - Enhancements for planetary missions
  - Up-to-date user interface : ergonomy, interactivity, link to office tools

- **New capabilities of Thermica version 4**

Import of CAD models

- **After a survey phase between Astrium and partners, a tool for CAD model import will be developped in 2003**

- **Major characteristics :**
  - Use of STEP format
  - Automatic creation of supported shapes
  - Show / No Show capabilities of objects
  - Pick of construction points for shape creation



FRAMEWORK of version 4 : main features

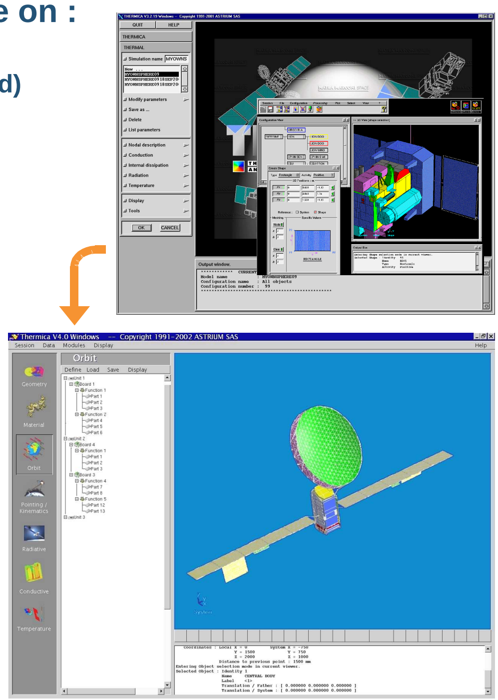
- **New GUI based on Open Source Software, available on :**
  SUN, HP, DEC, SGI, Windows, Linux
  (no need for external GUI packages such as Java or Exceed)

- **Modern look & feel**
  based on standard PC tools ergonomy

- **Improvement of interactive 3D graphics**
  (fully OpenGL)

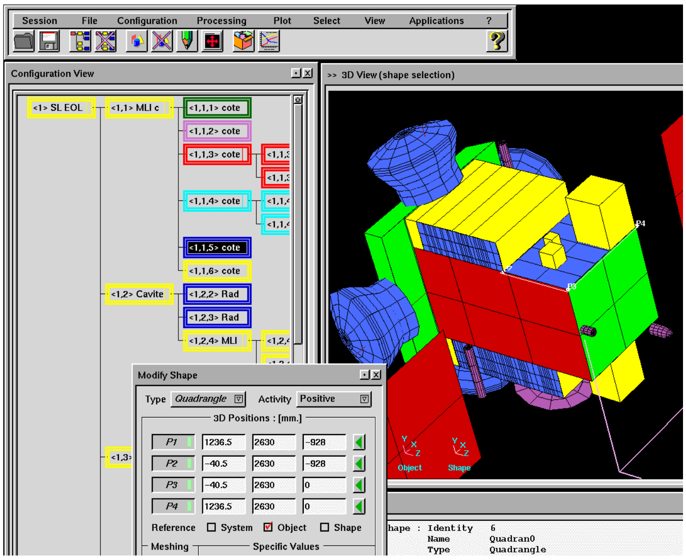
- **Better integration into PC office tools**
  - Copy/Paste from Thermica to PC clipboard
    → Insert of figures in Office documents
  - Results available in Excel format

- **Management of submodels**

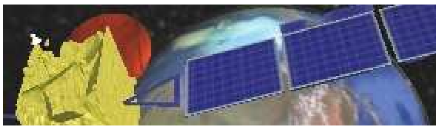


MODELER

- **Current capabilities (v3.2) :**
  - Interactive objects/shapes creation
  - Interactive pre-post-processing, with animations versus time
  - Pick of points/surfaces/objects/nodes and information feed-back
  - Interactive motions ($AXIS)
  - Material database management

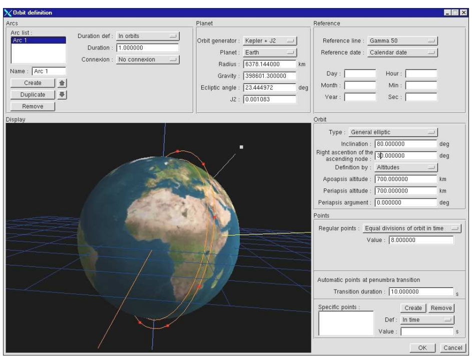


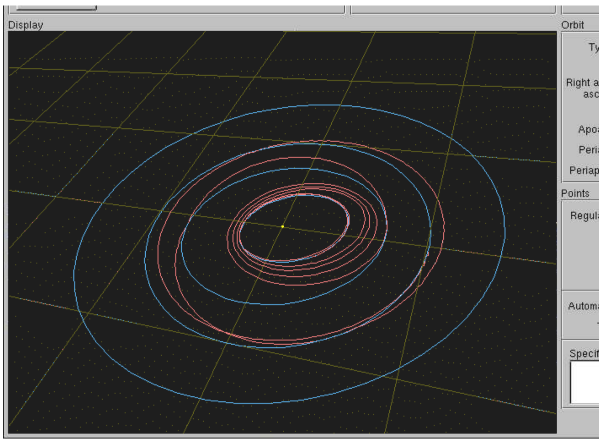
- **New features :**
  - Management of submodels
  - Easy use of construction points
  - Improvement of interactive motions
  - Management of textures for nice displays of coatings
  - Management of cutting operations



ORBIT module

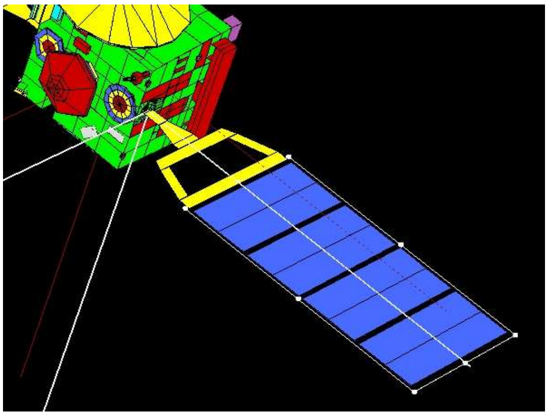
- **New <u>Kepler + J2</u> propagator**
- **Management of orbits around any planet of the solar system**
- **Modelisation of interplanetary missions**
- **New arc connexion by ΔV impulse**
- **Easy import of externally computed orbits (orbit = ASCII file)**
- **Interactive visualisation**





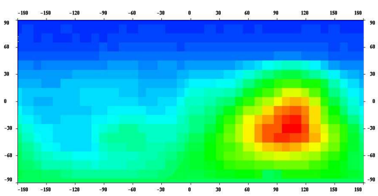
POINTING module

- **Synchronisation with orbital arcs is no more necessary**
- **In addition to the 14 existing pre-defined pointing directions :**
  Pointing towards any planet of the solar system…
  … from any planet of the solar system
- **Easy definition of general kinematic sequences :**
  - Translations and rotations given versus time
  - Movement from a given attitude to another in a given time
  - Movement with a given translation & rotation in a given time
- **Easy import of externally computed kinematics (kinematics = ASCII file)**
- **Interactive definition of mobile parts by picking in the 3D view**



RADIATIVE module (1/3)

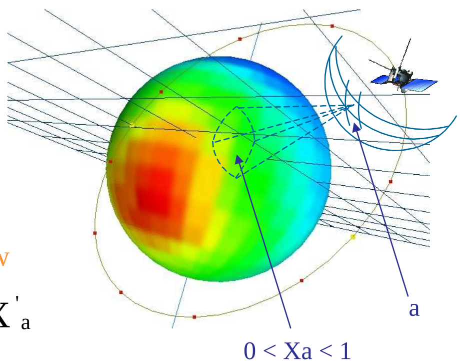
- **Planetary albedo and IR fluxes :**
  - Ability to take into account user-defined tables giving IR & albedo fluxes versus latitude, longitude and time
  - Useful for scientific missions (still used in Astrium) & LEO satellites with small inertia
  - Interactive display of tables



- **Natural enhancement of the existing algorithm :**
  - Integration of IR & albedo fluxes evaluated for each solid angle :

$$\Phi_{IR} = \overset{\text{now}}{\boxed{\sigma T^4}} \sum_a F_{S,a} X_a$$

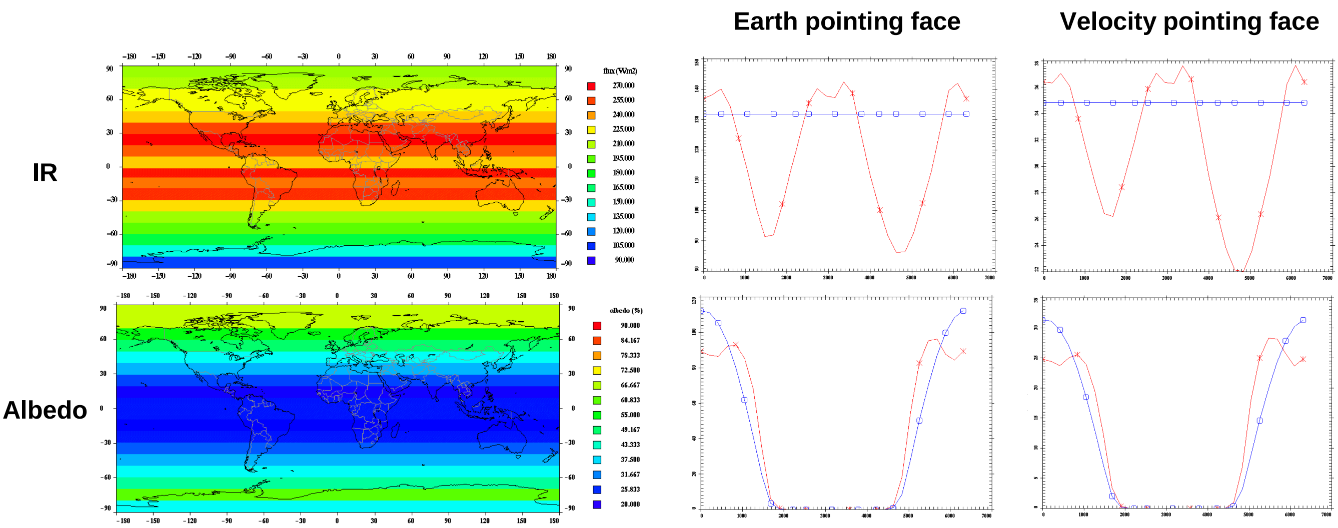
$$\Phi_a = C_{SUN} \overset{\text{now}}{\boxed{\rho_{Planet}}} \sum_a F_{S,a} X'_a$$



RADIATIVE module (2/3)

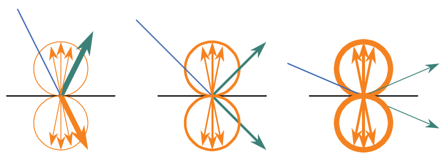
- **Comparison with the classical modelisation :**
  - Albedo & IR fluxes for a cube (α=0.4 ε=0.75) on a 1000 km heliosynchronous orbit with a 13.5 H solar time of the ascending node, at spring equinox

(Albedo & IR tables extracted from ‘Satellite Thermal Control Handbook’, D.G.Gilmore)



RADIATIVE module (3/3)

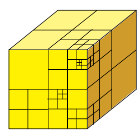
- **Improved thermo-optical properties :**
  absorption, reflexion and transmission coefficients depending on the light incidence angle (with respect to the surface normal)
  - Modelisation of some kind of BRDF
  - Tabulated thermo-optical properties
  - Properties re-evaluated for each incident ray
  - The outgoing direction remains lambertian or specular



- **Statistical accuracy control : improvement of large models management**
  → how much rays to emit to reach a given accuracy on REFs and fluxes

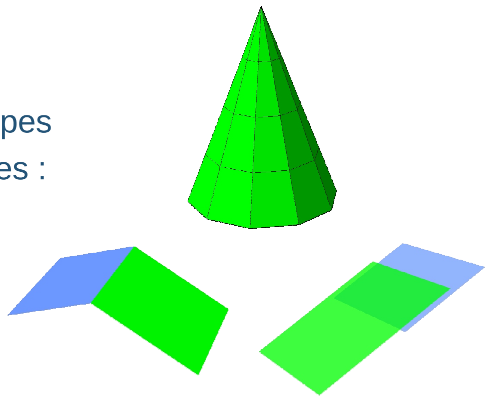
- **Memory management for REF reciprocity law enforcement :**
  → no more entire (n×n) matrix in memory (n=number of radiative nodes)
  → no more size limit for radiative nodes

- **Improved ray tracing : adaptive size of voxels**
  - Better memory management
  - Faster computations for large models

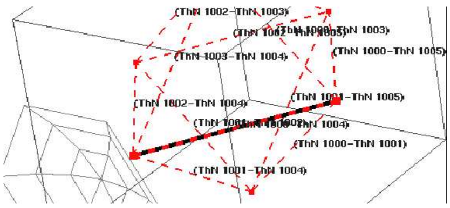


CONDUCTION module

- **Current capabilities (v3.2) :**
  - Automatic computation of couplings inside shapes
  - Automatic detection of contacts between shapes :
    - Edge contact
    - Surface on top of another surface
  - Modelisation of contact resistance

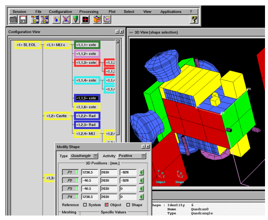


- **New features :**
  - Interactive display / selection / definition of couplings in the 3D display

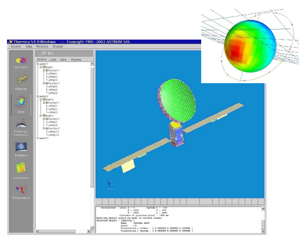


Development status / availability

- **Version 3.2.19 : december 2002**
  - Statistical accuracy control enhancement
  - REF reciprocity law enforcement :
    no more limit on the nb of radiative nodes
  - Availability of the modeler



- **Version 4 : june 2003**
  - Orbit / Pointing / Radiative / Conductive modules
    - Batch algorithms performed, validation phase ending
    - User interface + interactive plotting : under development
  - Framework, Modeler : still under development



- **Delay due to harmonisation effort :**
  - Generic environment for all SYSTEMA modules
  - Ability to plug any new module / application in a modern interactive framework

Appendix S: ESATAN/FHTS and ESARAD: a View on the Near Future

ESATAN/FHTS and ESARAD:
a View on the Near Future

J. Thomas
Alstom

October 2002

ESATAN/FHTS & ESARAD: A View on the Near Future.

Julian Thomas
Frédéric du Laurens d'Oiselay

ALSTOM

ESARAD v5.2 (5.3 release)

- *Improved* Assembly & mission pointing method
- *New* calculate "Lumped Parameter" conductance
- *New* Msc/Nastran -> ESARAD "erg" converter
- *New* interactive hierarchy building
- *New* recursive attribute editing
- *New* platform independent data store
- *New* user defined utility menu

ESARAD Next Version

ALSTOM

- Automatic Conductor Generation
- Pointing Module

ESARAD Next Version

ALSTOM

- Automatic Conductor Generation
- Pointing Module

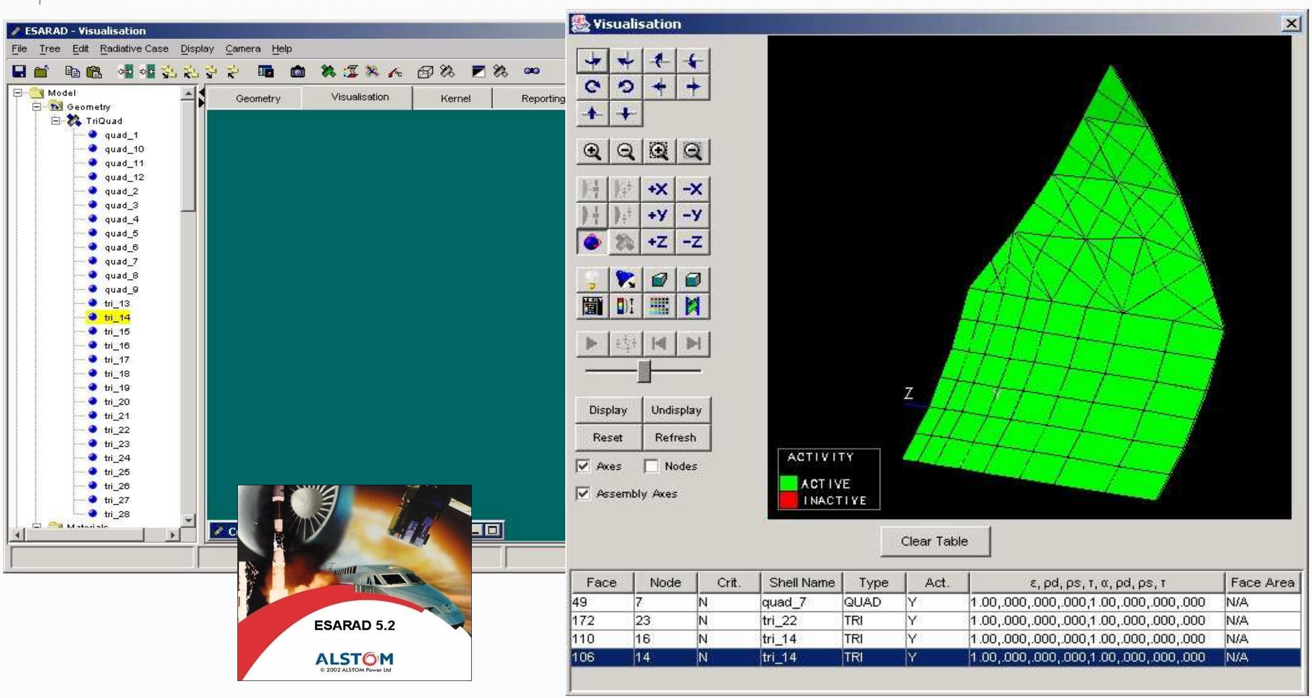
Automatic Conductor Generation

- First phase in next version
  - Internal conductances calculated
  - Inter-shell conductances identified
  - Limited to uncut shells

- Second phase
  - Internal conductances calculated
  - Inter-shell conductances calculated
  - Unlimited to uncut shells

- Plan -

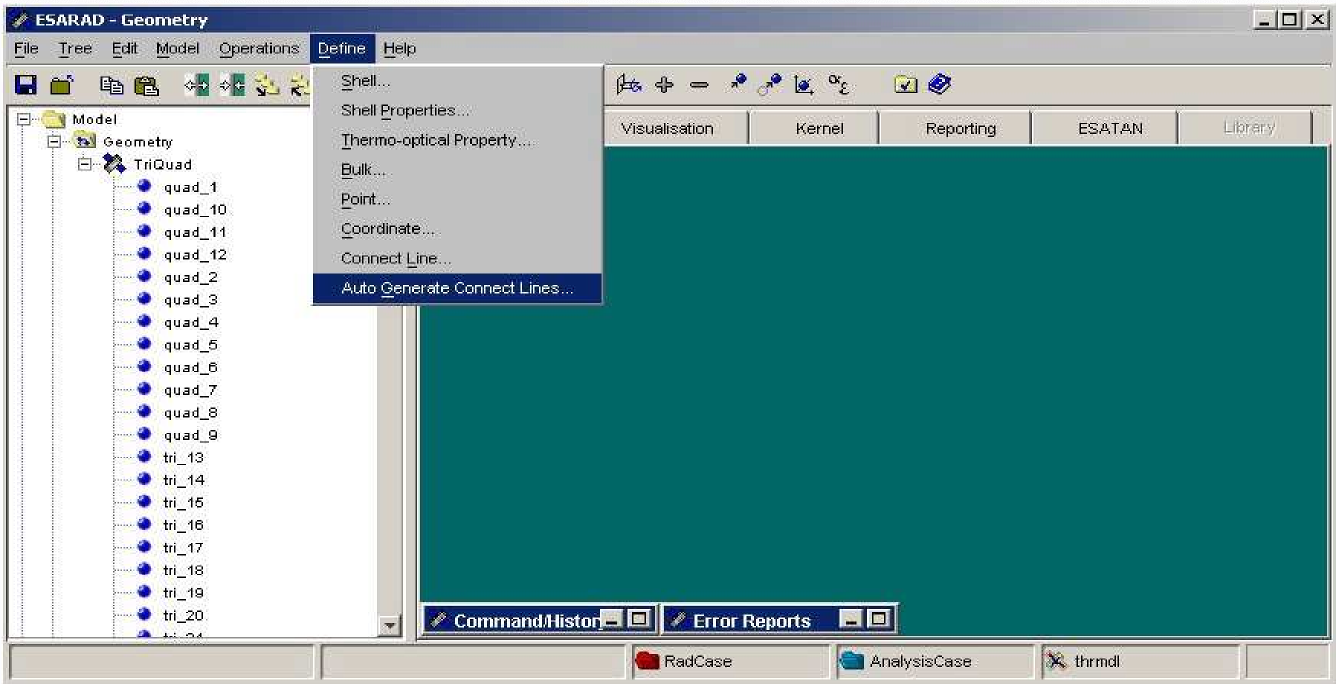
Automatic Conductor Generation



- Model TriQuad -

Automatic Conductor Generation

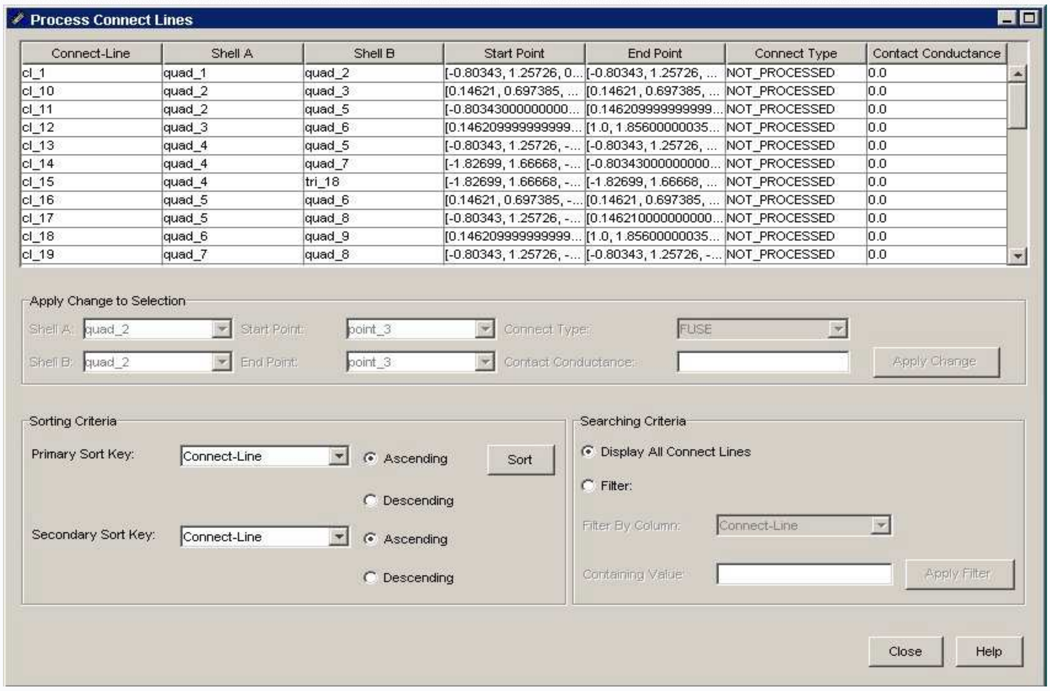
ALSTOM



- Operation -

Automatic Conductor Generation

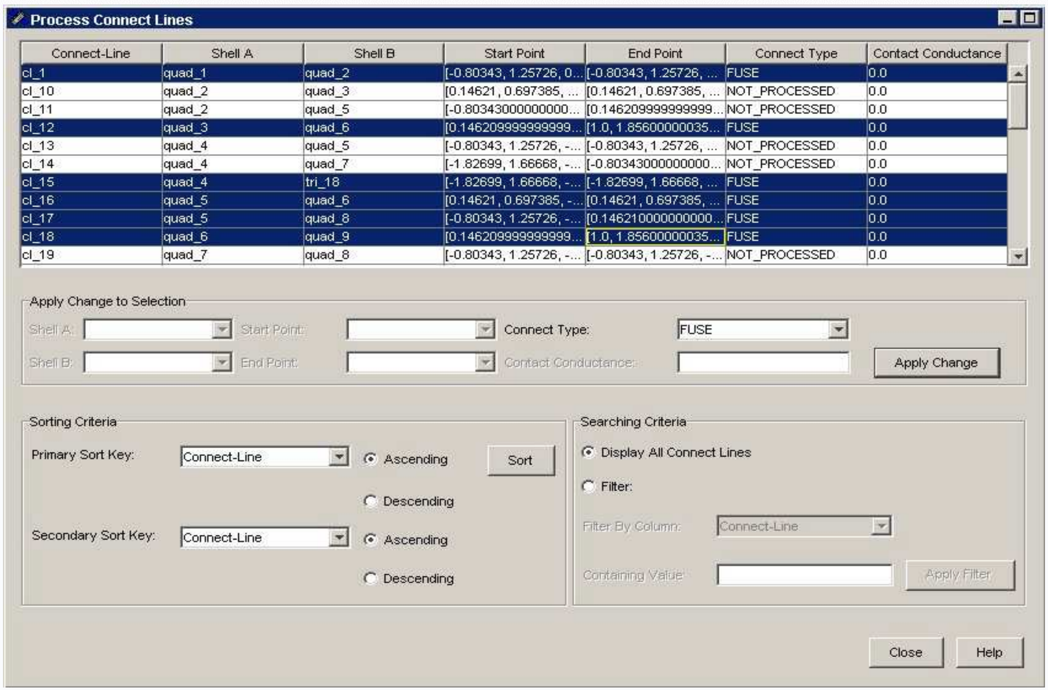
ALSTOM



- Connect Lines Definition -

Automatic Conductor Generation

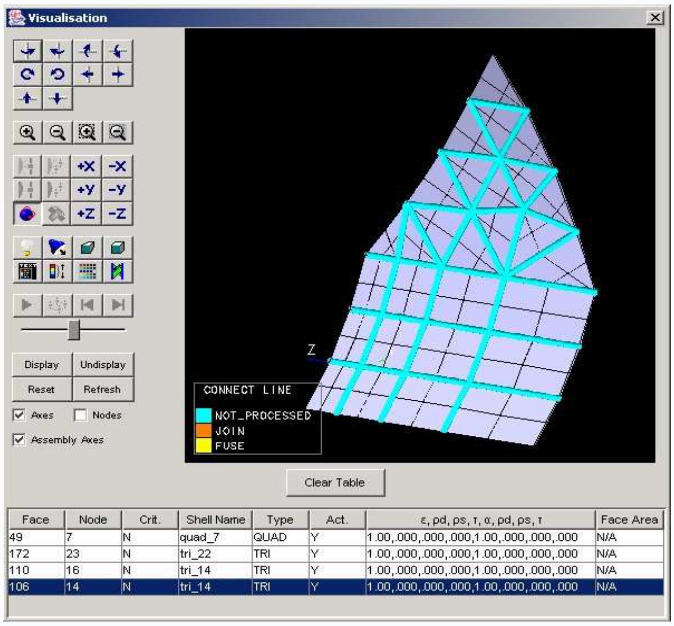
ALSTOM

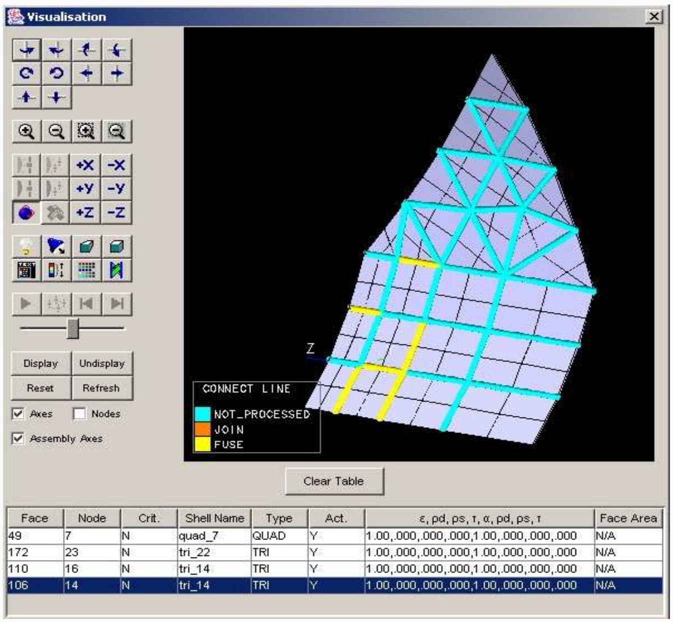


- Processing Multiple Connect Lines -

Automatic Conductor Generation

ALSTOM

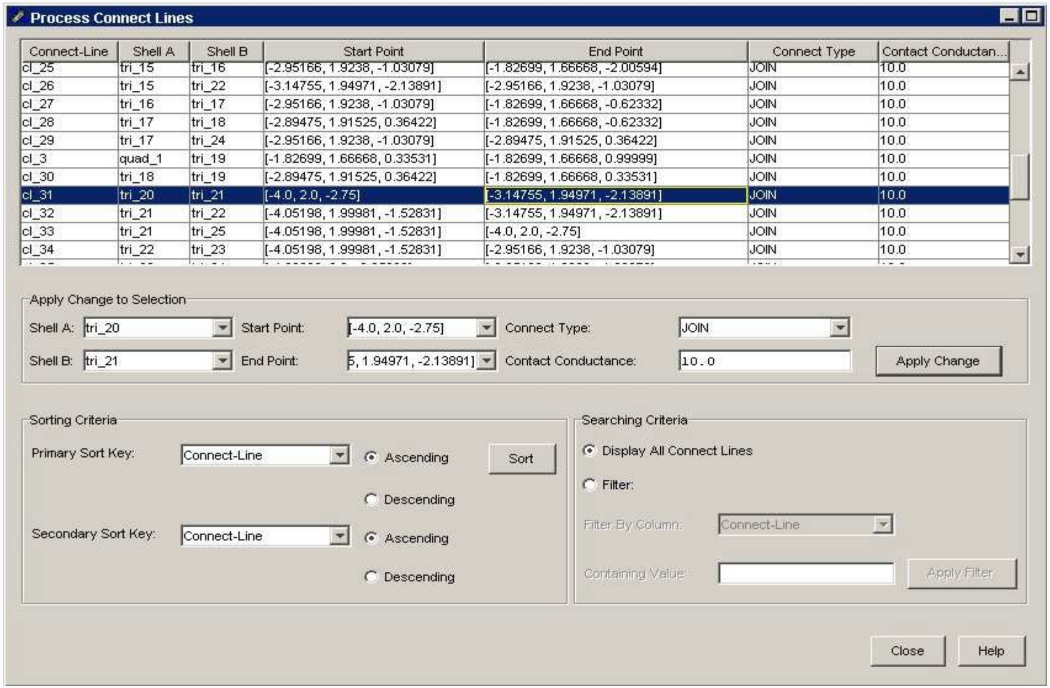




- Visualisation -

Automatic Conductor Generation

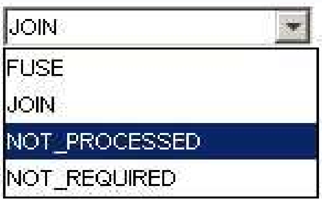
ALSTOM



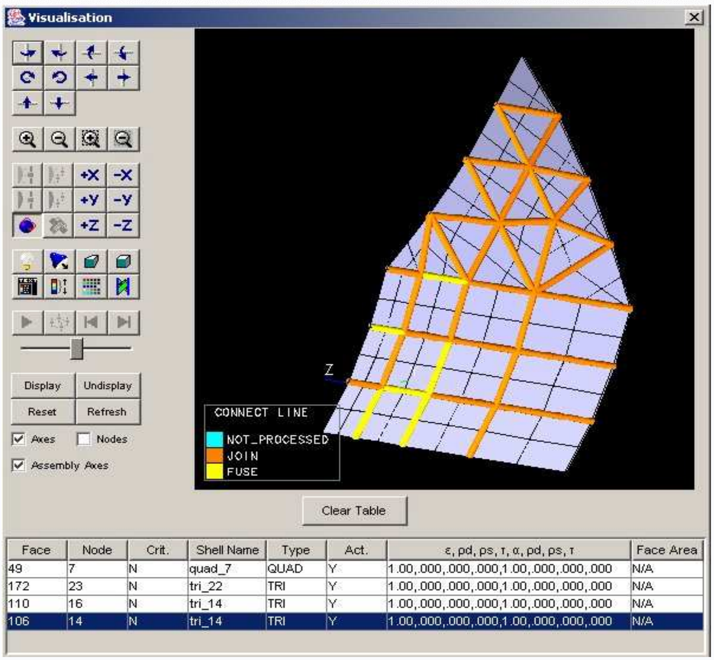
- Processing Single Connect Line -

Automatic Conductor Generation

ALSTOM



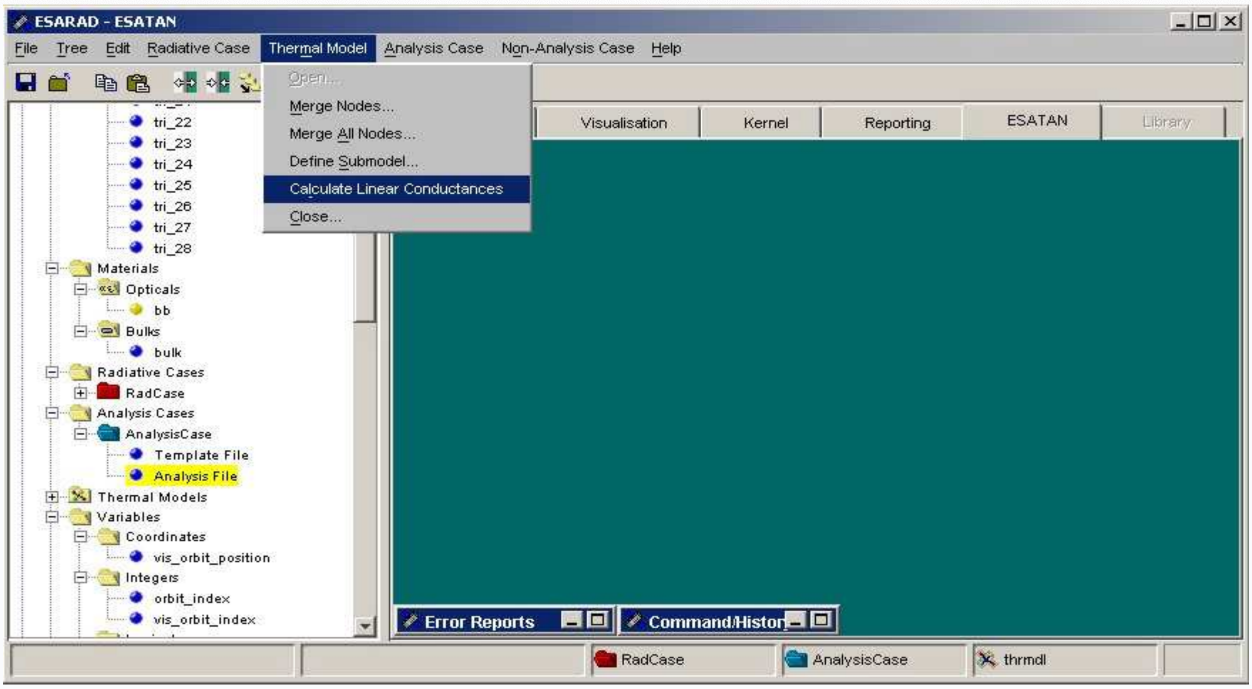
- Connect lines
  - Fuse = perfect contact
  - Join = contact conductance required
  - Not required = ignored



- Types of Connect Lines -

Automatic Conductor Generation

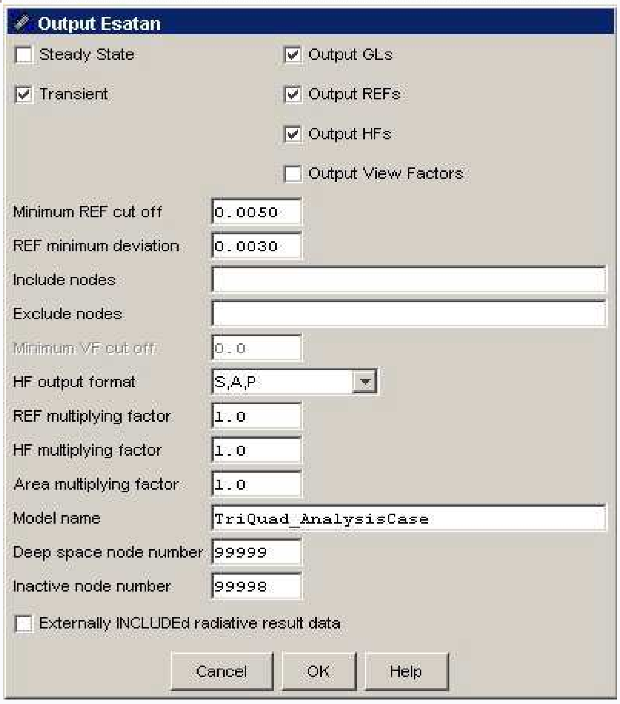
ALSTOM



- Types of Connect Lines -

Automatic Conductor Generation

ALSTOM




```
# Esarad version 5.2.7, run date 20:28 Sun 20 Oct 2002
# Model name: TriQuad          Analysis case: AnalysisCase
# template file: Template.tpl
# Esarad version 5.2.7, run date 20:28 Sun 20 Oct 2002
# Model name: TriQuad          Analysis case: AnalysisCase
$MODEL TriQuad_AnalysisCase
  $LOCALS
  $NODES
    D1 , T = 0.000000,
     A = 0.366379, ALP = 1.000000, EPS = 1.000000;
    D2 , T = 0.000000,
     A = 0.732755, ALP = 1.000000, EPS = 1.000000;
    D3 , T = 0.000000,
     A = 1.099135, ALP = 1.000000, EPS = 1.000000;
    D4 , T = 0.000000,
     A = 1.627537, ALP = 1.000000, EPS = 1.000000;
    D5 , T = 0.000000,
     A = 1.789569, ALP = 1.000000, EPS = 1.000000;
    D6 , T = 0.000000,
     A = 1.951600, ALP = 1.000000, EPS = 1.000000;
    D7 , T = 0.000000,
     A = 2.347327, ALP = 1.000000, EPS = 1.000000;
    D8 , T = 0.000000,
     A = 2.581000, ALP = 1.000000, EPS = 1.000000;
                         //
     GR(29, 99999) = 1.17991;
     GR(30, 99999) = 0.683219;
     GR(31, 99999) = 0.513277;
     GL(14,21) =  U
     GL(1,3) = k_bulk * 0.0829264;
     GL(1,20) =  U
     GL(2,2) =  U
     GL(2,3) = k_bulk * 0.0301475;
     GL(2,4) = k_bulk * 0.0829255;
     GL(3,3) =  U
     GL(3,4) =  U
     GL(3,5) = k_bulk * 0.0829265;
     GL(3,19) =  U
     GL(3,20) =  U
     GL(4,4) =  U
     GL(4,5) =  U
     GL(4,6) = k_bulk * 0.0574988;
     GL(4,19) =  U
     GL(5,5) =  U
     GL(5,6) =  U
     GL(5,7) = k_bulk * 0.0574973;
     GL(6,6) =  U
     GL(6,7) =  U
     GL(6,8) = k_bulk * 0.0574979;
     GL(6,18) =  U
     GL(7,7) =  U
     GL(7,8) =  U
     GL(7,9) = k_bulk * 0.0398667;
```

- Outputing GLs -

ESARAD Next Version

ALSTOM

- Automatic Conductor Generation

- Pointing Module

- Summary -

ESARAD Next Version

ALSTOM

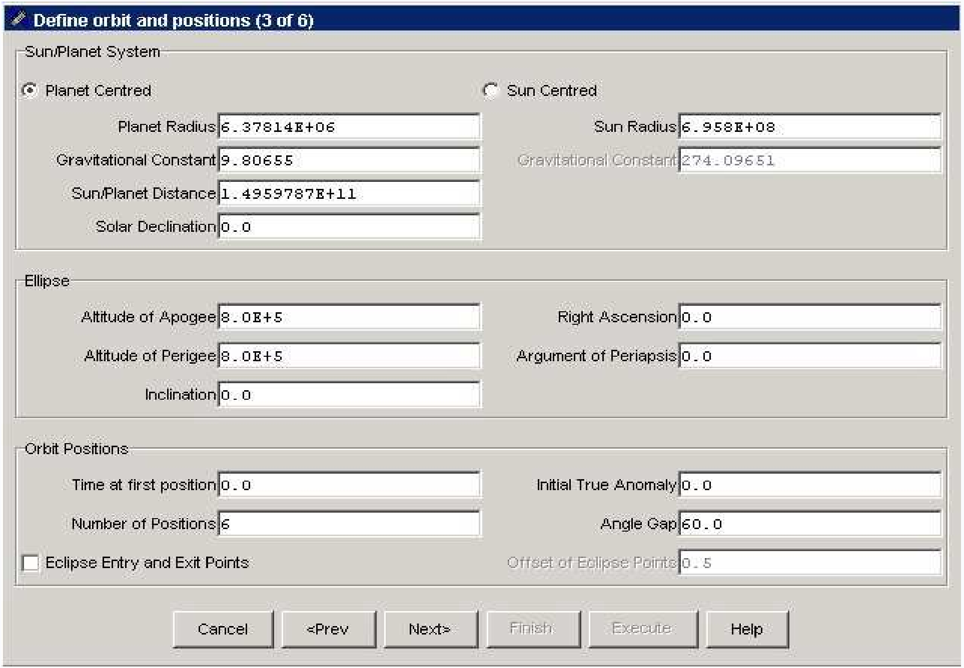
- Automatic Conductor Generation

- Pointing Module

- Summary -

Radiative Case Definition

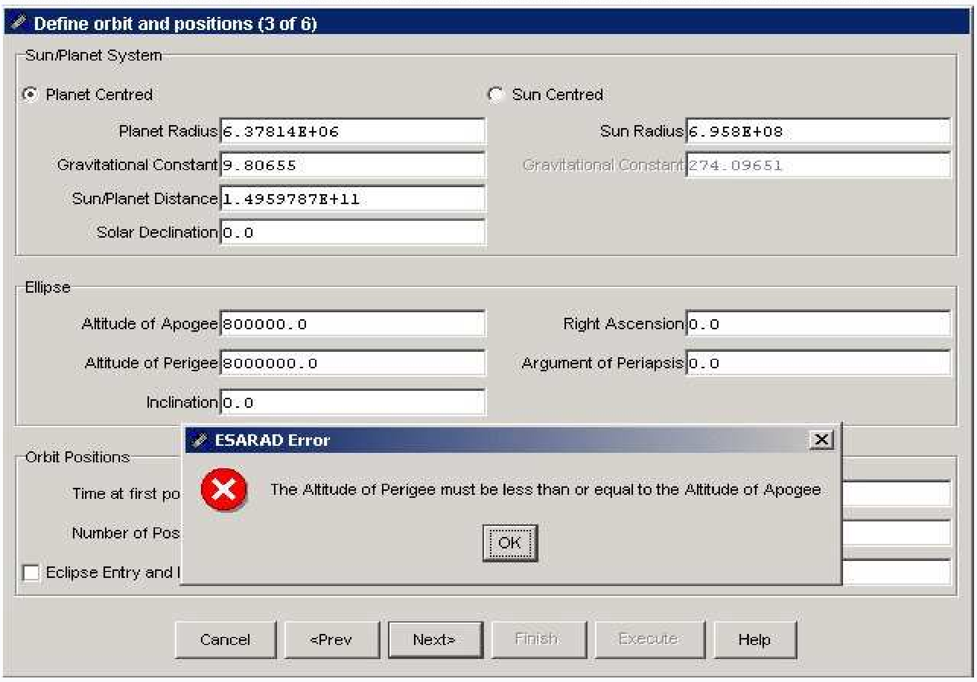
ALSTOM



- New Layout -

Radiative Case Definition

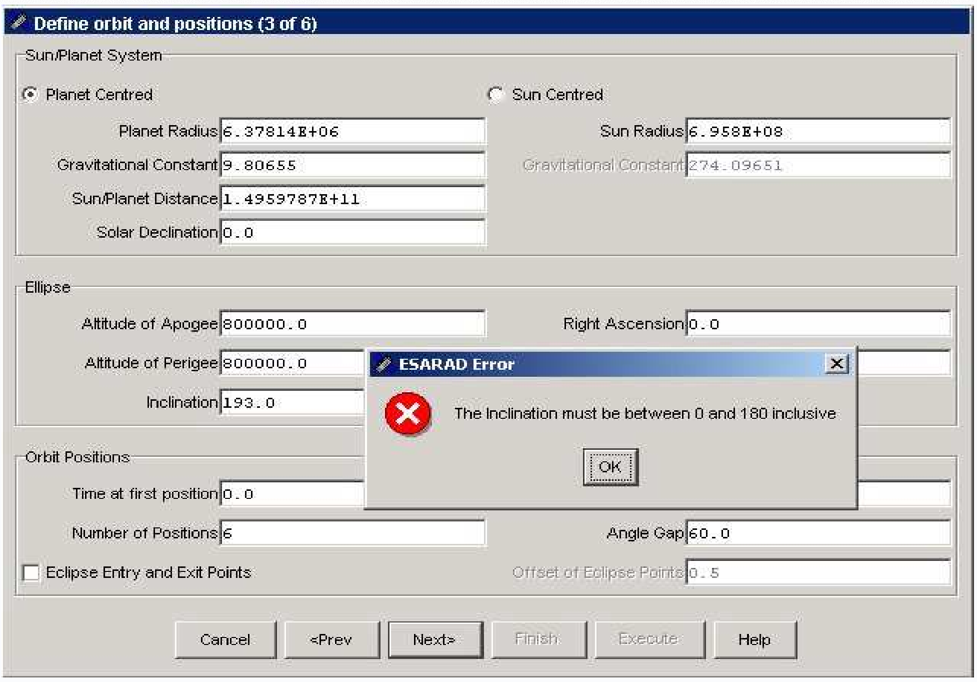
ALSTOM



- Interactive Input Checking -

Pointing Module

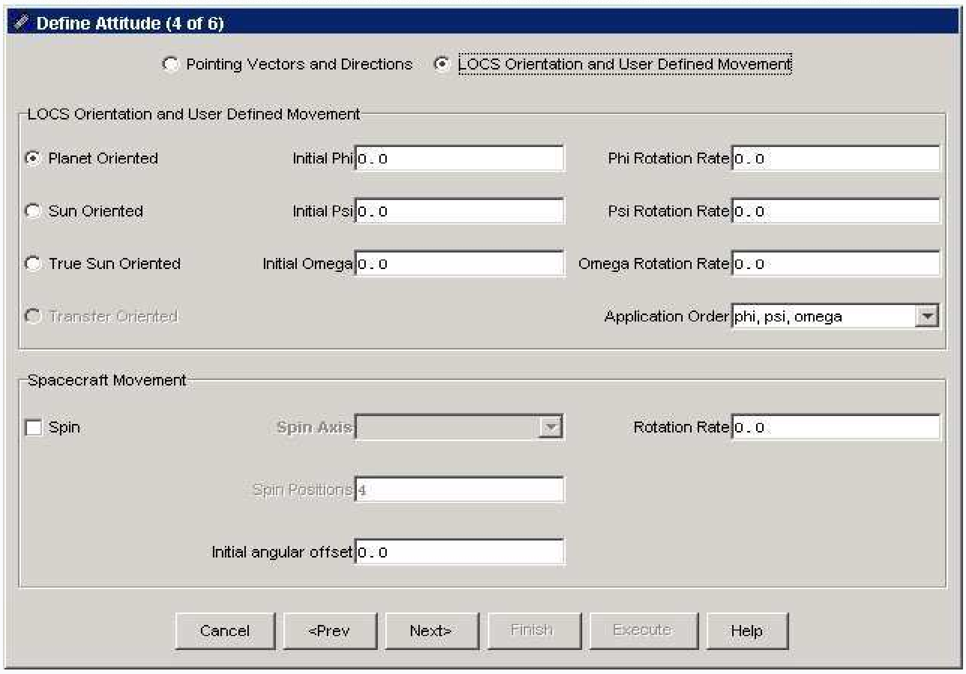
ALSTOM



- Interactive Input Checking -

Pointing Module

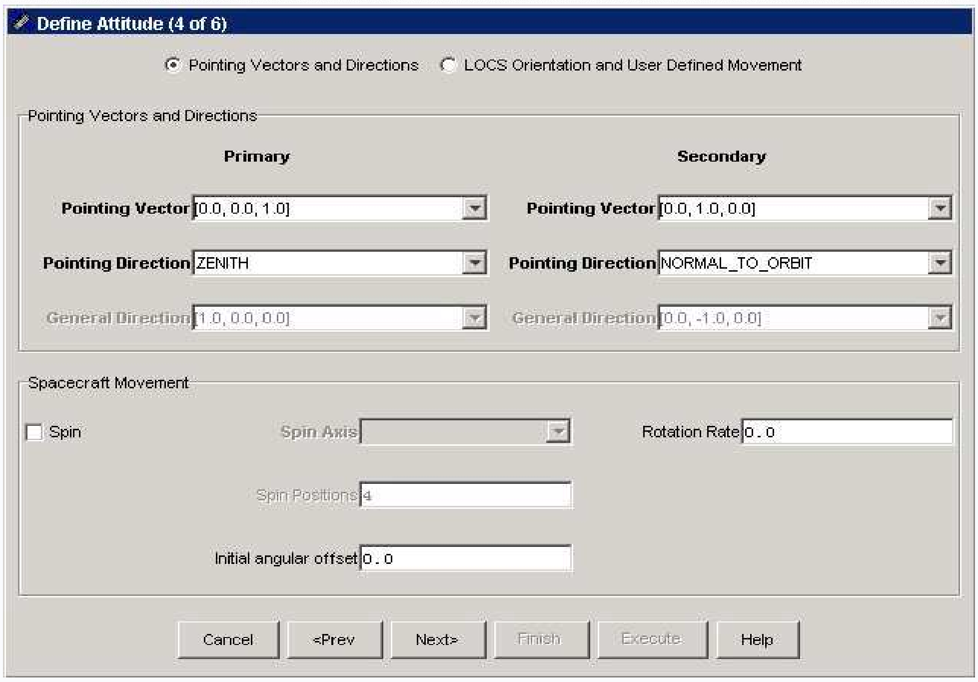
ALSTOM



- Classical LOCS Orientation -

Pointing Module

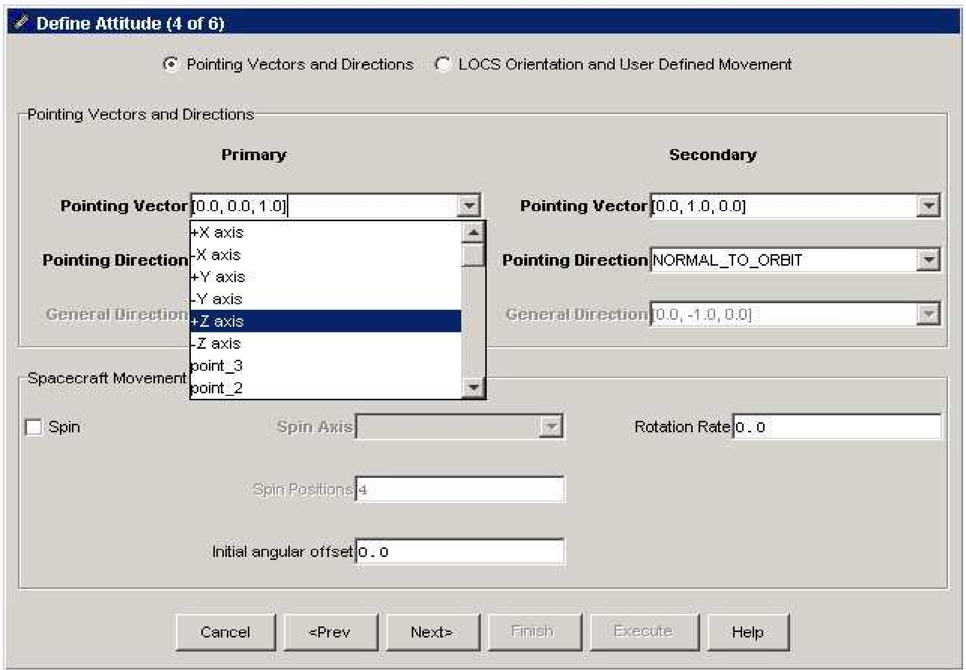
ALSTOM



- Primary and Secondary Pointing -

Pointing Module

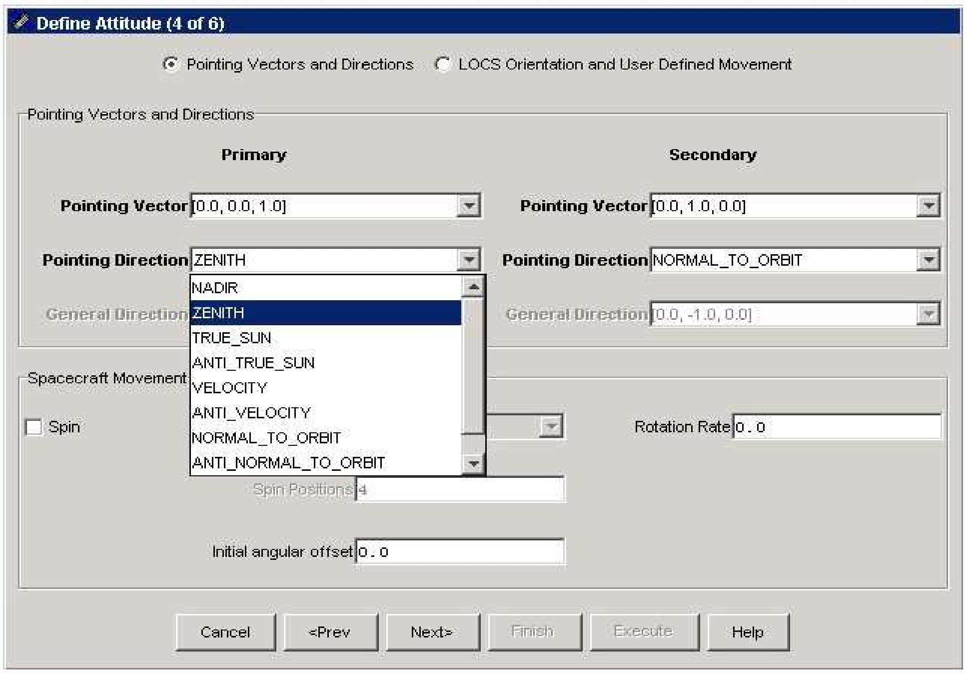
ALSTOM



- Pointing Vectors -

Pointing Module

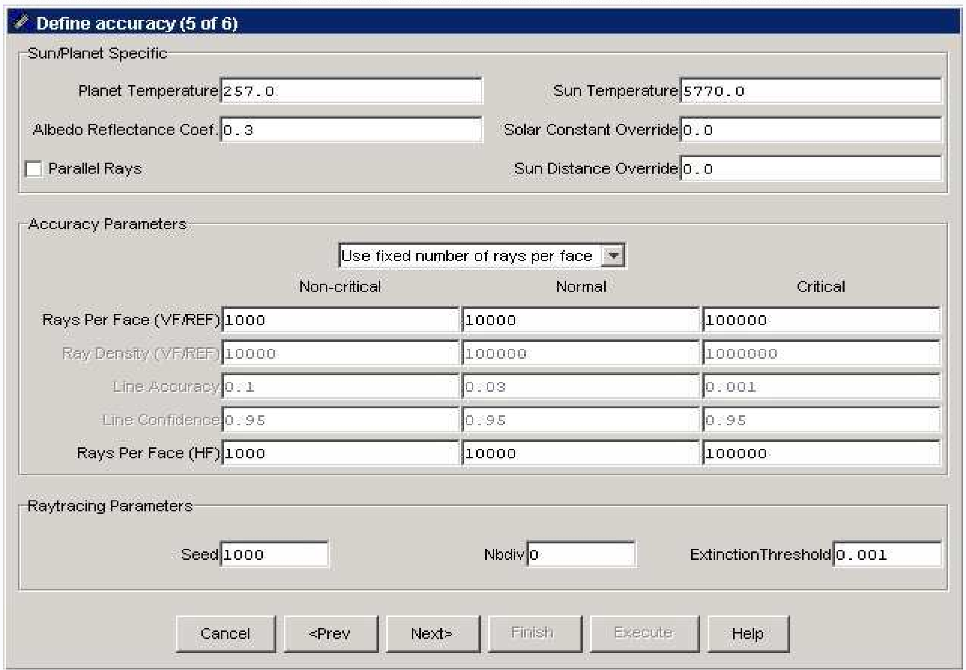
ALSTOM



- Pointing Directions -

Calculations

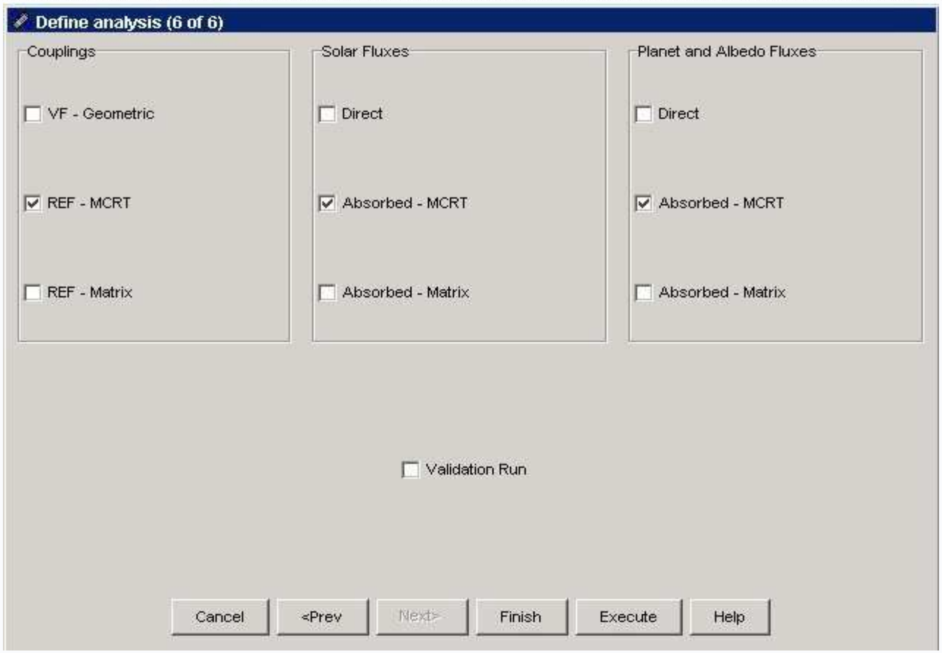
ALSTOM



- Accuracy Parameters -

Calculations

ALSTOM

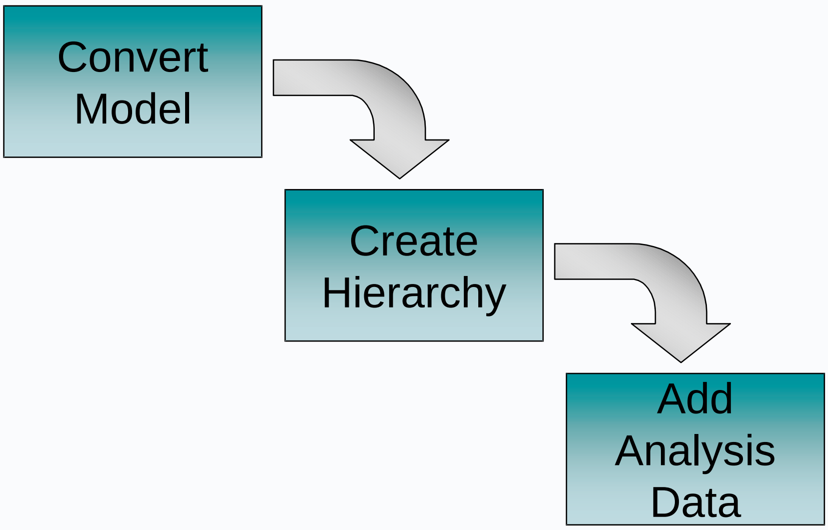


- Classical Options -

Import from MSc/Nastran

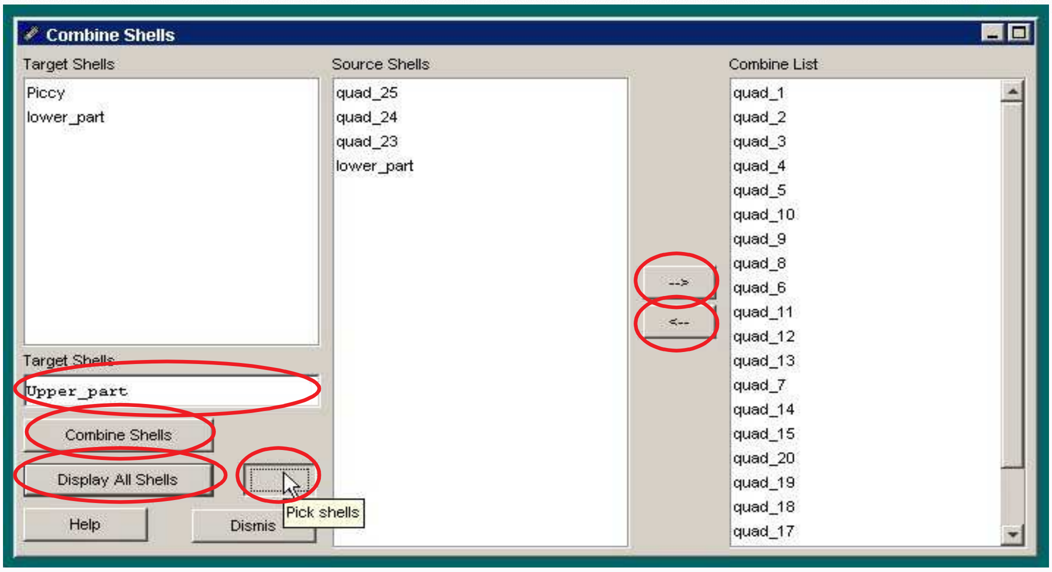
ALSTOM

Process View



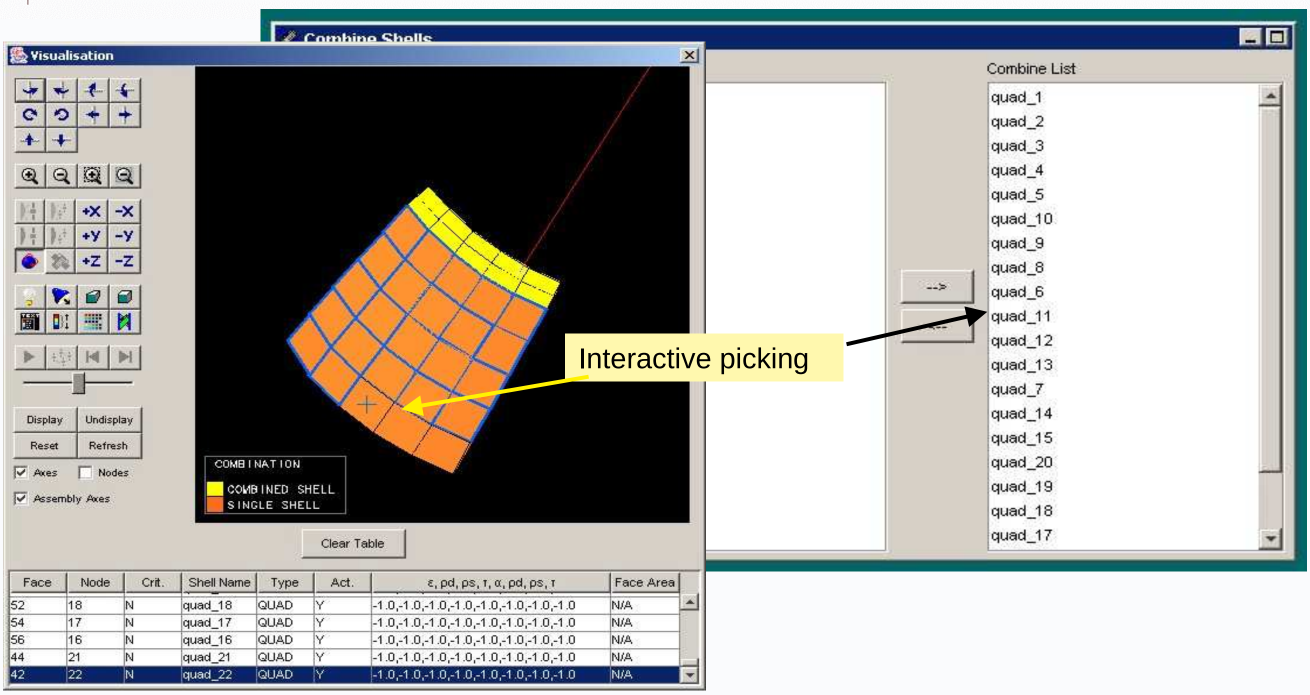
- “Round Trip” Convertion in Planning -

New “Combine” Dialog



- Rapid Model Structuring -

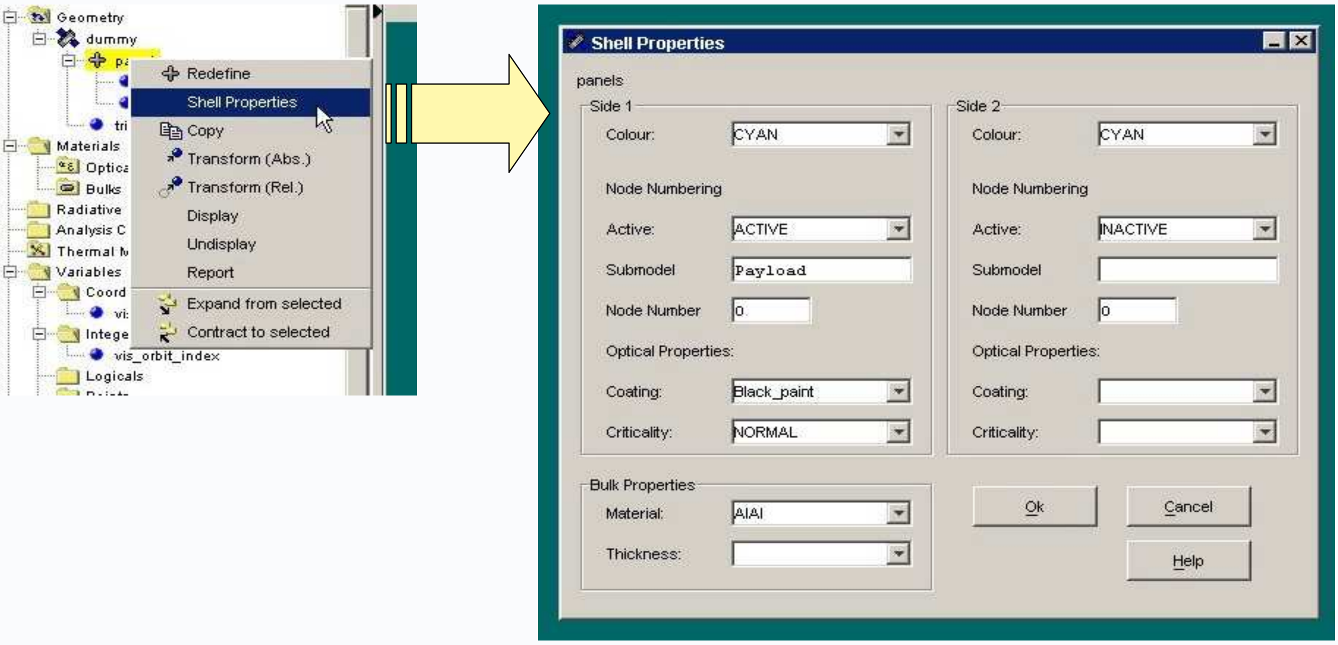
New “Combine” Dialog



- Rapid Model Structuring -

Recursive Attribute Editing

ALSTOM

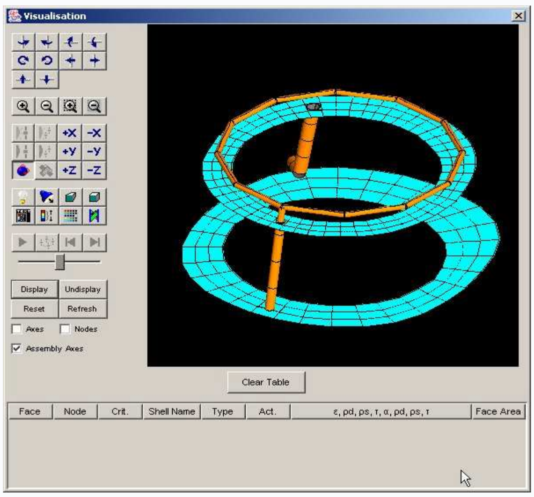


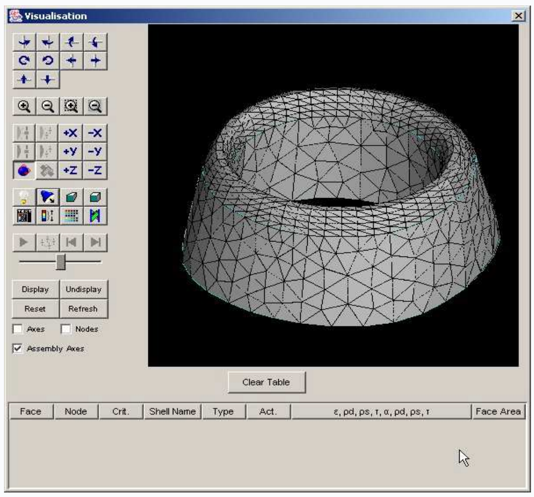
- Rapid Analysis Model Development -

MSc/Nastran Derived Models

ALSTOM

Nacelle Modelling at Technology Centre



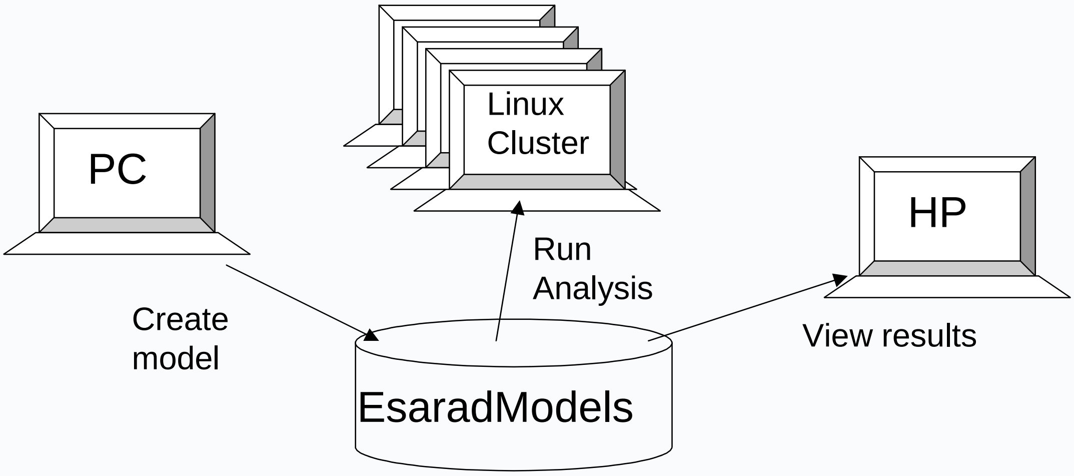


- -

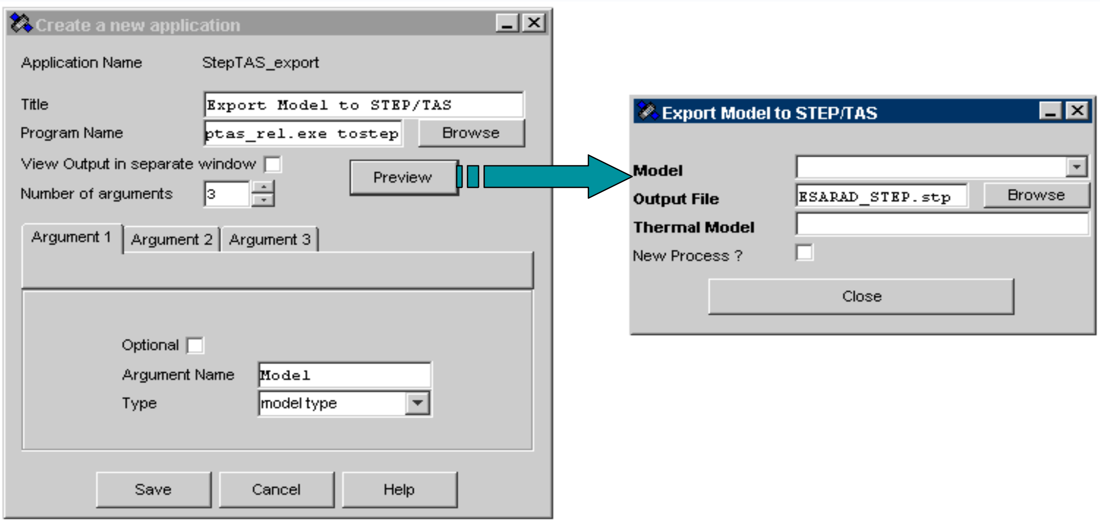
"HDF" Model Store

Platform Independent Data Store

- Build anywhere / analyse anywhere / post-process anywhere.
  - Example:



Utility Menu



Into next year...

ALSTOM

- STEP/AP203 (v5.3?)
- Further major releases planned of ESARAD & ESATAN under project "POLYTAN"
- ESATAN and FHTS enhancements
- OpenGL Visualisation
- ThermXL v3

www.techcentreuk.power.alstom.com

- Commitment to Continuous Improvement -

ALSTOM

www.alstom.com

Appendix T: TASverter: Thermal Analysis for Space model converter

TASverter:
Thermal Analysis for Space
model converter

S. Appel
ESTEC/TOS-MCV

TASverter

Thermal Analysis for Space model converter

Hans Peter de Koning and Simon Appel

(Hans-Peter.de.Koning@esa.int) (simon@thermal.esa.int)

(ESA/ESTEC D/TOS-MCV, The Netherlands)

16th European Workshop on Thermal and ECLS Software

ESA/ESTEC, Noordwijk (ZH), The Netherlands

22-23 October 2002

Topics

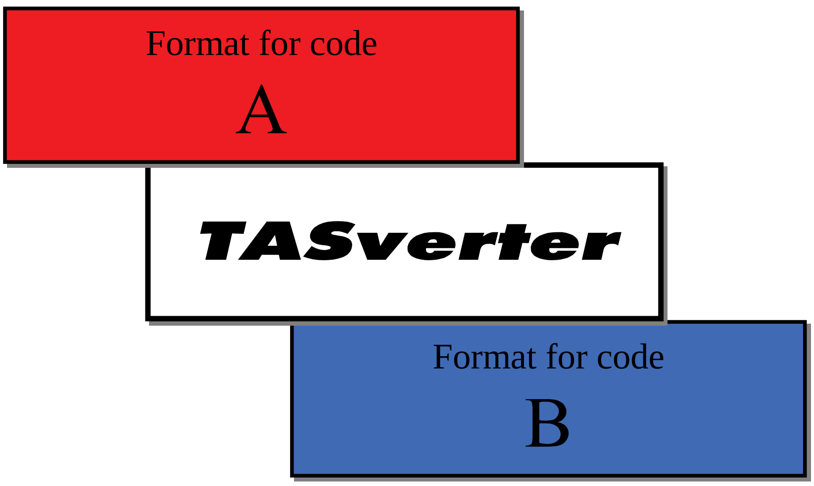
- Why TASverter ?
- Purpose of TASverter
- Supported formats
- Approach
- Current status
- How to get it?
- Further STEP-TAS developments

Why TASverter ?

- STEP-TAS converters did not deliver industrial solution up to now
- TASverter is an initiative of ESA/ESTEC D/TOS-MVC to:
  - → Offer users finally a working solution for exchange of thermal models between major analysis tools
  - → Remove complicated dependency on (at least) 3 developers
    - STEP-TAS library developer
    - Analysis tool A developer
    - Analysis tool B developer
  - → Produce a fully functional tool and basis for future industrial versions
  - → Produce a framework for verification of data exchange standard(s) and implementations

Purpose of TASverter

Convert thermal analysis models
from format of software code A to format for software code B



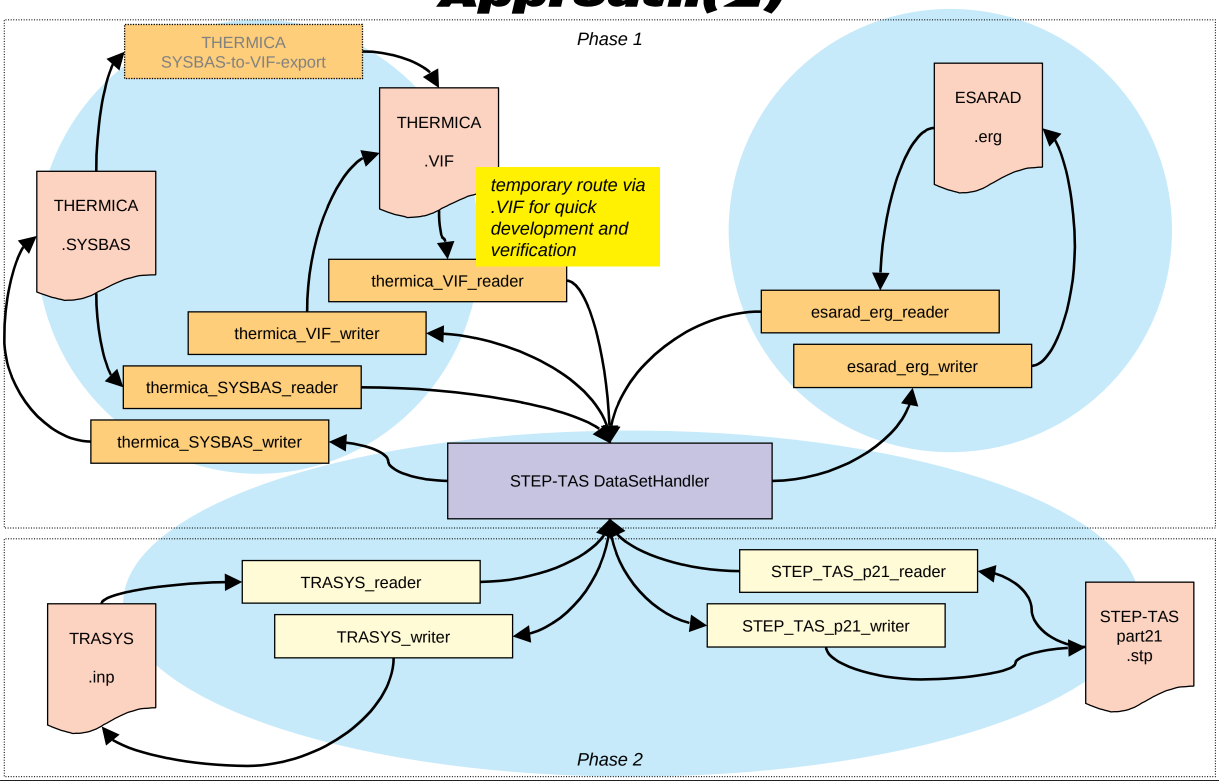
Supported formats

- Before end of 2002
  - → Thermica SYSBAS
  - → Thermica VIF
  - → ESARAD .erg
  - → STEP-TAS .stp (ISO 10303 Part 21, version STEP-TAS-ARM/2)
- Beginning of next year
  - → TRASYS .inp
- Possible further extensions
  - → MSC/PATRAN, TSS, ...
  - → User requests

Approach(1)

- For each format a reader and a writer is created
- Internal data storage is based on STEP-TAS data structure
  - → STEP-TAS DataSetHandler,
    automatically generated with *pyExpress* (STEP-EXPRESS compiler)
- Fine-tuning and simplification of the STEP-TAS standard
  - → Support all model features: more shapes, mirroring, user-defined coordinate transformations, full assembly tree
  - → Goal is to be able to recreate a thermal model which is as much as possible understandable and editable by humans
  - → Updated STEP-TAS standard will be released for inclusion in ECSS and ISO TC184/SC4 (STEP committee)

Approach(2)

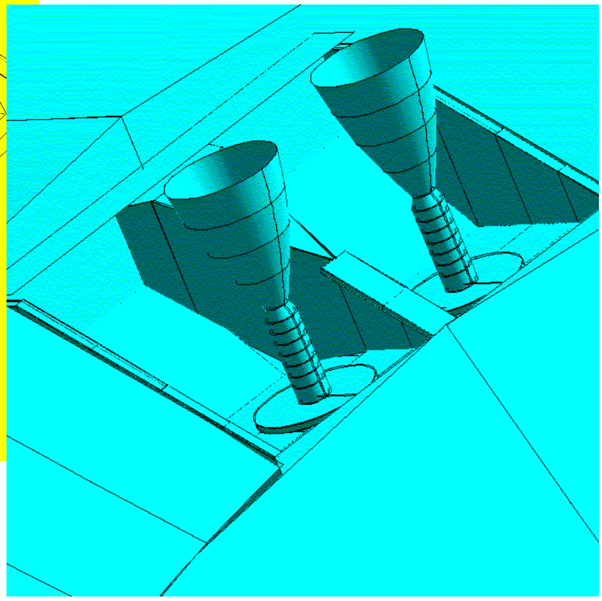


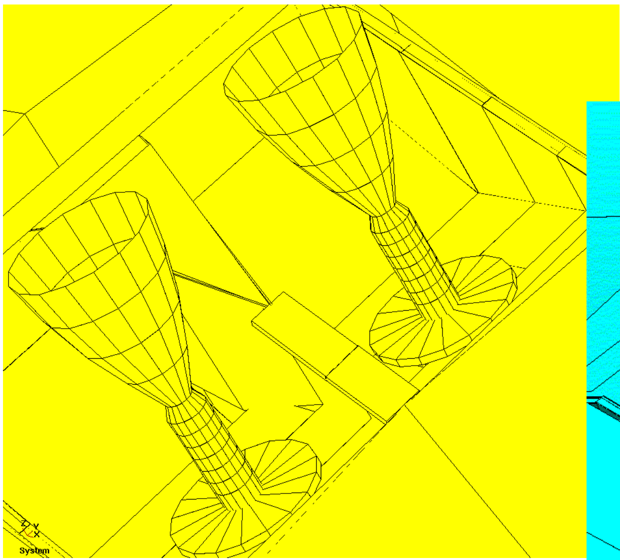
Current status (1)

- pyExpress STEP-TAS DataSetHandler is almost complete
- Thermica VIF_reader and VIF_writer are in testing phase
- Thermica SYSBAS_reader is in testing phase
- ESARAD erg_writer is in testing phase
- ESARAD erg_reader and Thermica SYSBAS_writer are under construction

Current status (2)

ESARAD model





Thermica model
VIF-format

How can you get it?

As soon as it is available the Windows executable can be downloaded freely from:

http://www.estec.esa.int/thermal/tools

Please send an E-mail to: Hans-Peter.de.Koning@esa.int

And we let you know when the software is available.

Further STEP-TAS developments

- Formal standardisation in frame of ECSS / ISO
- C++ STEP-TAS library developed by Simulog (ready 2003-Q1)
  - → No more dependency on third party software
  - → C-API migration path from current STEP-TAS library will be provided
  - → Pure ANSI C++
  - → Will be distributed in source code, so tool vendor can compile/link on any platform/compiler
  - → High performance: processes ~50000 STEP instances per minute on typical PC
- TASverter with SINDA / ESATAN exchange
  - → SINDA85 -> ESATAN converter already available
  - → With full user-definable unit conversion
  - → AP203 import

Appendix U: ThermXL v2 and Beyond

ThermXL v2
and Beyond

J. Thomas
Alstom

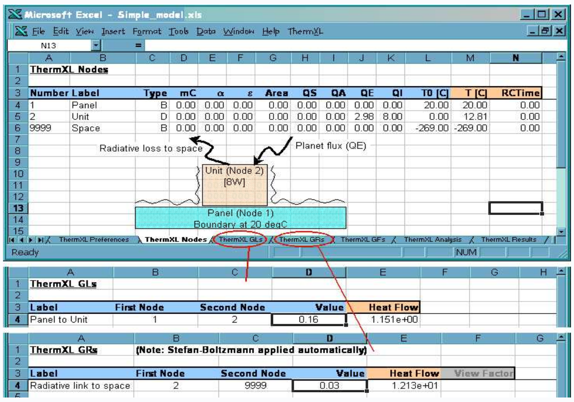
October 2002

ThermXL v2 & Beyond

Julian Thomas

Spreadsheet Thermal Analysis

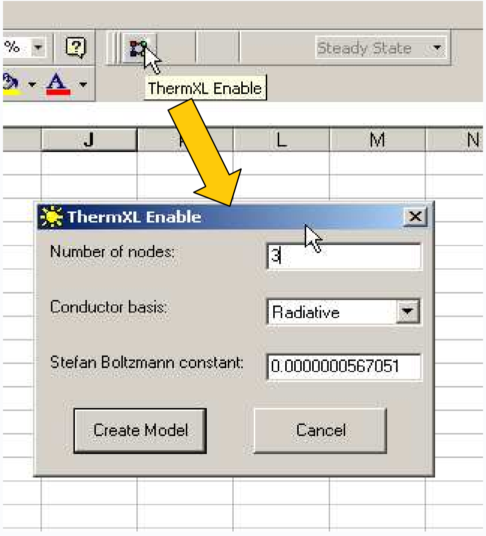
- Overview of ThermXL
- New features of v2 (released June 2002)
- Upcoming developments



ThermXL Overview

ALSTOM

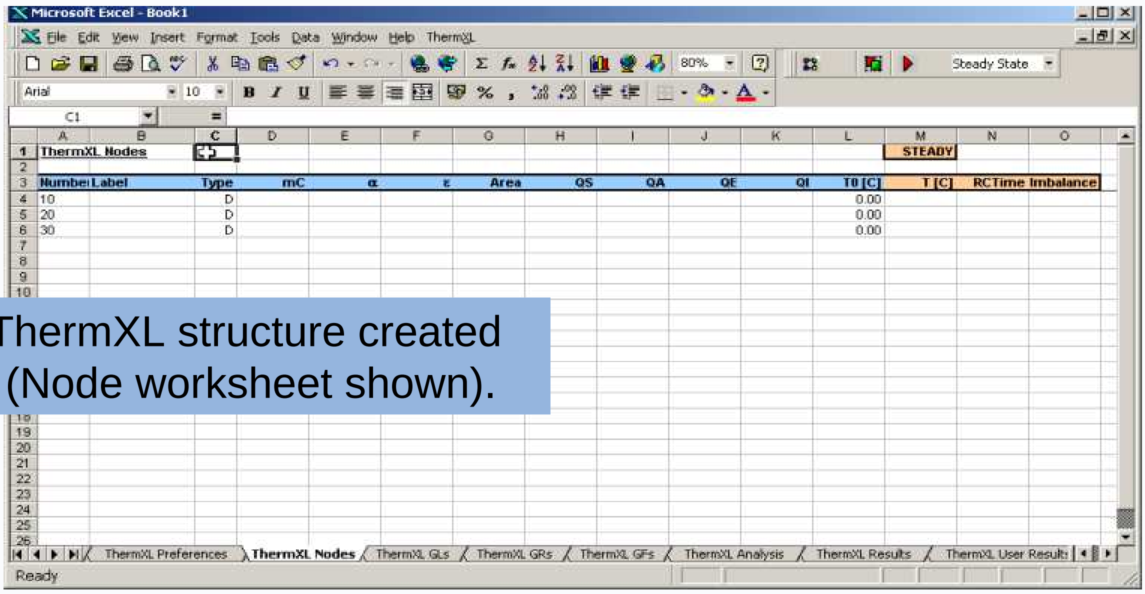
Create a new ThermXL model with 3 nodes...



- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM

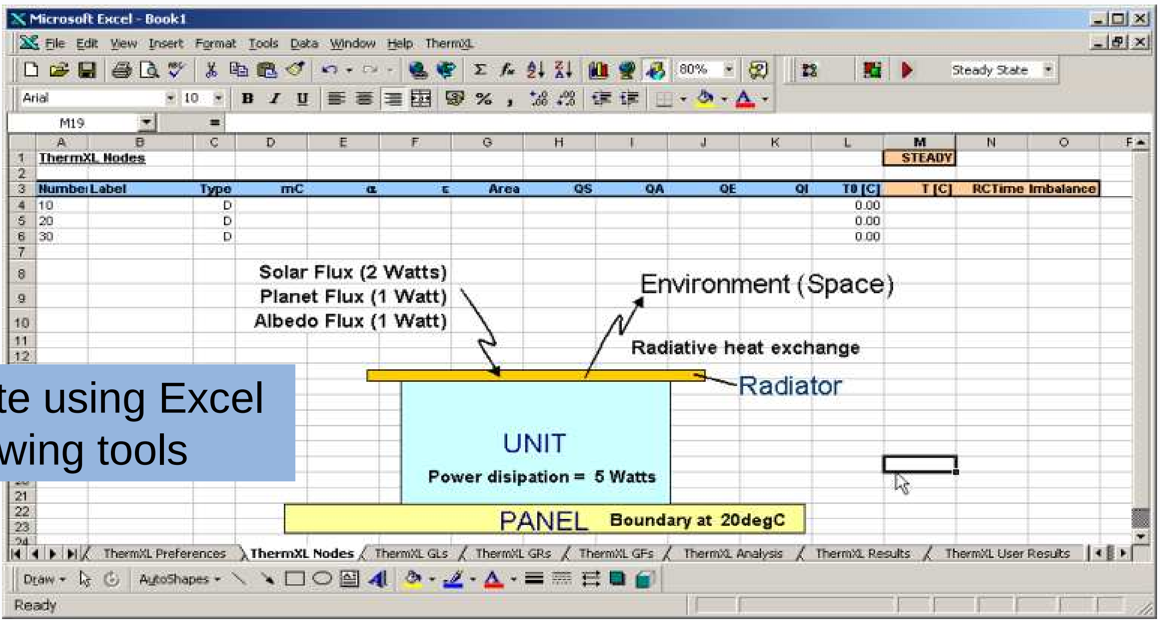


ThermXL structure created (Node worksheet shown).

- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM

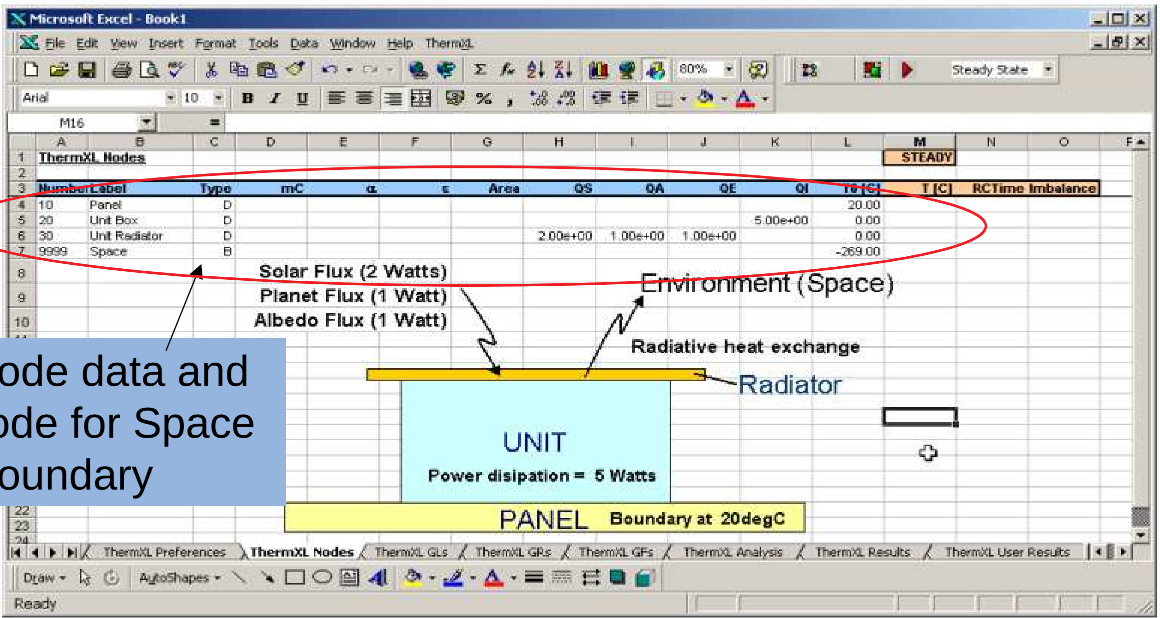


Annotate using Excel drawing tools

- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM



Add Node data and new node for Space boundary

- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

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Microsoft Excel - Workshop_TXL_pt1.xls

	A	B	C	D	E
1	ThermXL GLs				
2					
3	Label	First Node	Second Node	Value	Heat Flow
4	Panel to Unit	10	20	2.00e-01	
5	Unit to Radiator	20	30	1.00e-01	

ThermXL Preferences / ThermXL Nodes / ThermXL GLs / ThermXL GRs / ThermXL GFs / ThermXL Analysis / ThermXL Results / ThermXL User Results

Add Linear Conductors (GLs) to link up the model.

- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM

Microsoft Excel - Workshop_TXL_pt1.xls

D4 = 0.05

	A	B	C	D	E	F
1	ThermXL GRs	(GRs are directly defined as values)				
2						
3	Label	First Node	Second Node	Value	Heat Flow	View Factor
4	Radiator to Space	30	9999	5.00e-02		

ThermXL Preferences / ThermXL Nodes / ThermXL GLs / ThermXL GRs / ThermXL GFs / ThermXL Analysis / ThermXL Results / ThermXL User Results

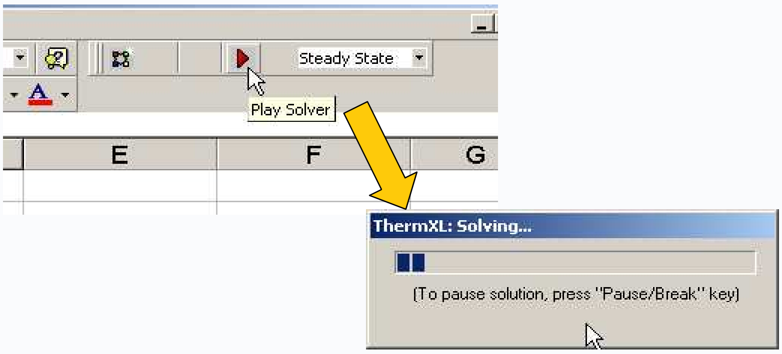
Add Radiative Conductor (GR) from Unit radiator to Space.

- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM

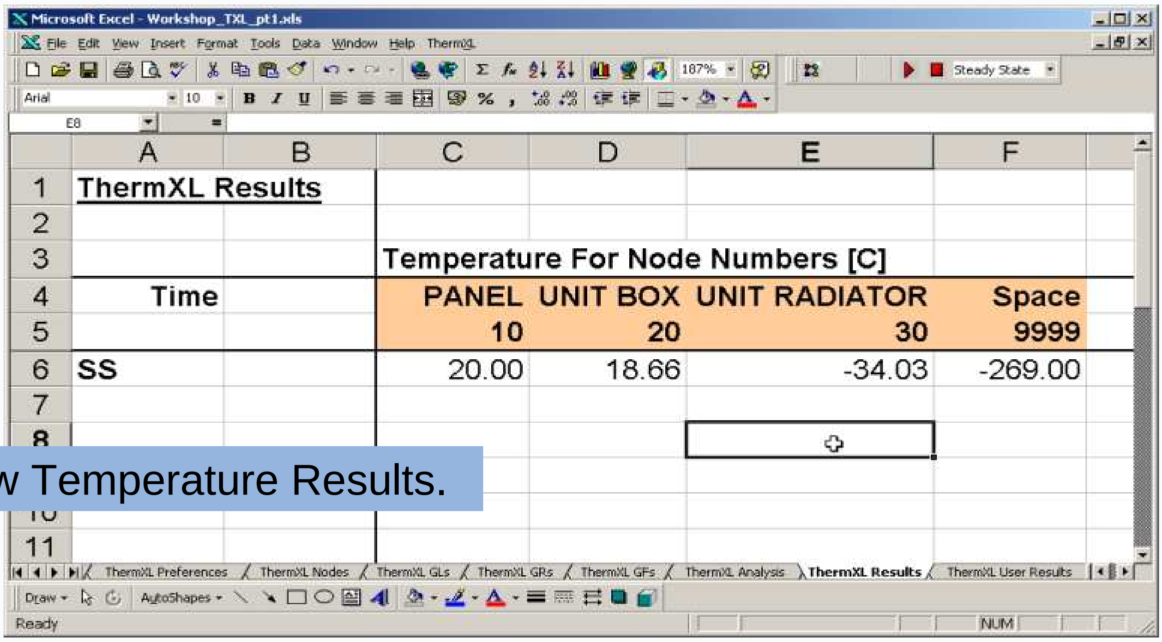
Run the analysis...



- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM



	A	B	C	D	E	F
1	ThermXL Results					
2						
3			Temperature For Node Numbers [C]			
4		Time	PANEL	UNIT BOX	UNIT RADIATOR	Space
5			10	20	30	9999
6	SS		20.00	18.66	-34.03	-269.00

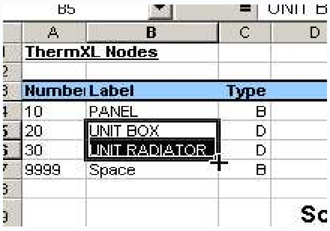
View Temperature Results.

- SCREENSHOT FROM LIVE DEMO -

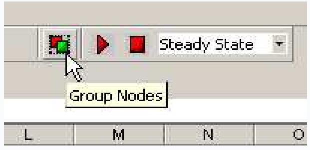
ThermXL Overview

Define some simple groups...

Select nodes...



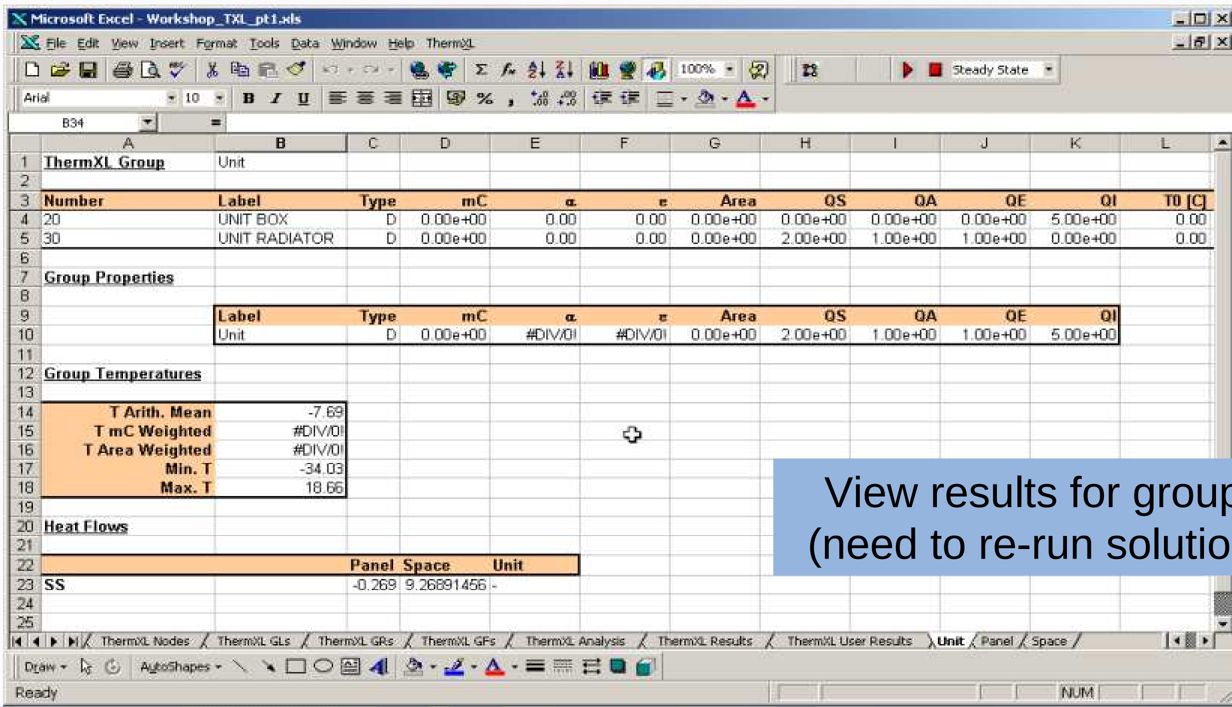
then ...



Create group named ‘Unit’ then...
Add groups for ‘Space’ and ‘Panel’

- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview



ThermXL Group Unit

Number	Label	Type	mC	α	ε	Area	QS	QA	QE	QI	T0 [C]
20	UNIT BOX	D	0.00e+00	0.00	0.00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	5.00e+00	0.00
30	UNIT RADIATOR	D	0.00e+00	0.00	0.00	0.00e+00	2.00e+00	1.00e+00	1.00e+00	0.00e+00	0.00

Group Properties

Label	Type	mC	α	ε	Area	QS	QA	QE	QI
Unit	D	0.00e+00	#DIV/0!	#DIV/0!	0.00e+00	2.00e+00	1.00e+00	1.00e+00	5.00e+00

Group Temperatures

T Arith. Mean	-7.69
T mC Weighted	#DIV/0!
T Area Weighted	#DIV/0!
Min. T	-34.03
Max. T	18.66

Heat Flows

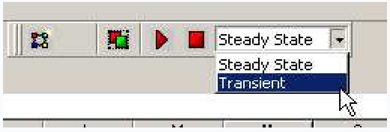
	Panel	Space	Unit
SS	-0.269	9.26891456	-

View results for groups (need to re-run solution).

- SCREENSHOT FROM LIVE DEMO -

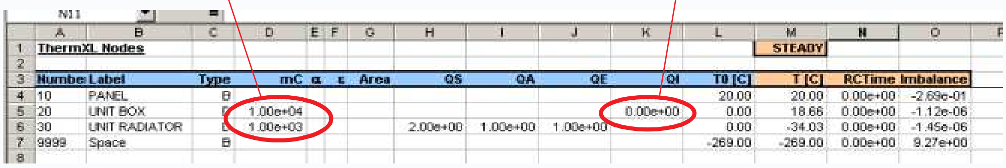
ALSTOM

Set-up for transient case...



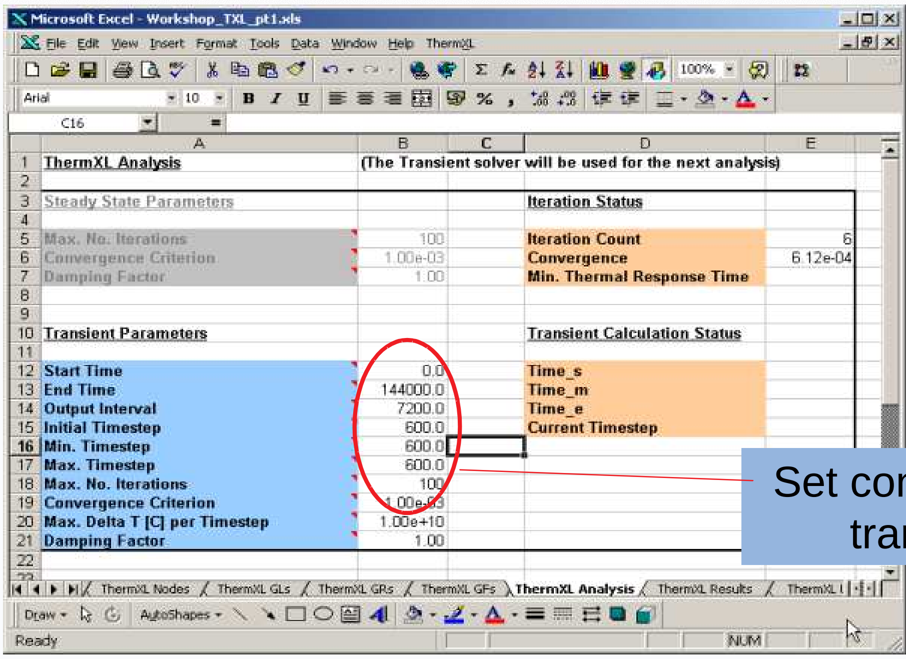
Define heat capacity

Remove power



- SCREENSHOT FROM LIVE DEMO -

ALSTOM



Set control values for transient run.

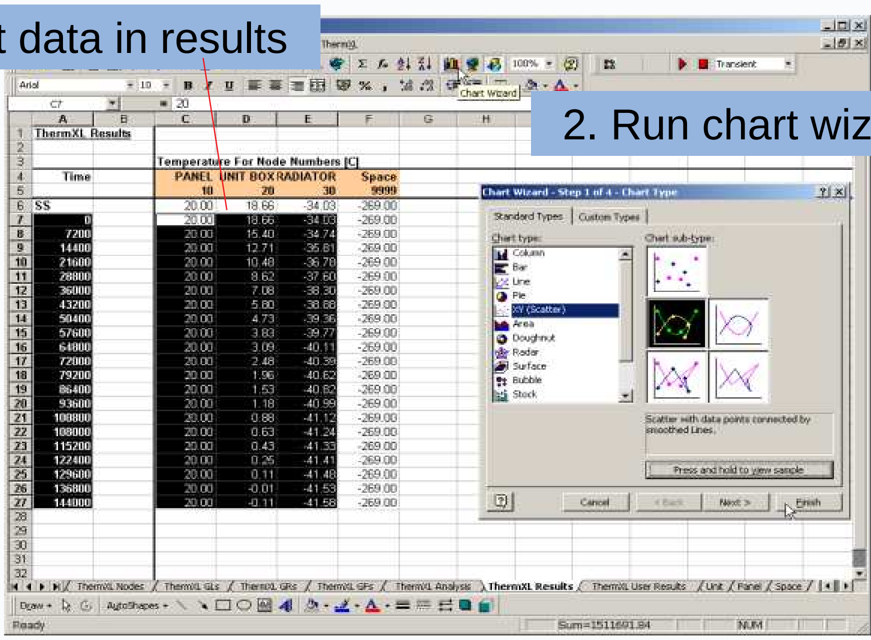
- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM

1. Select data in results

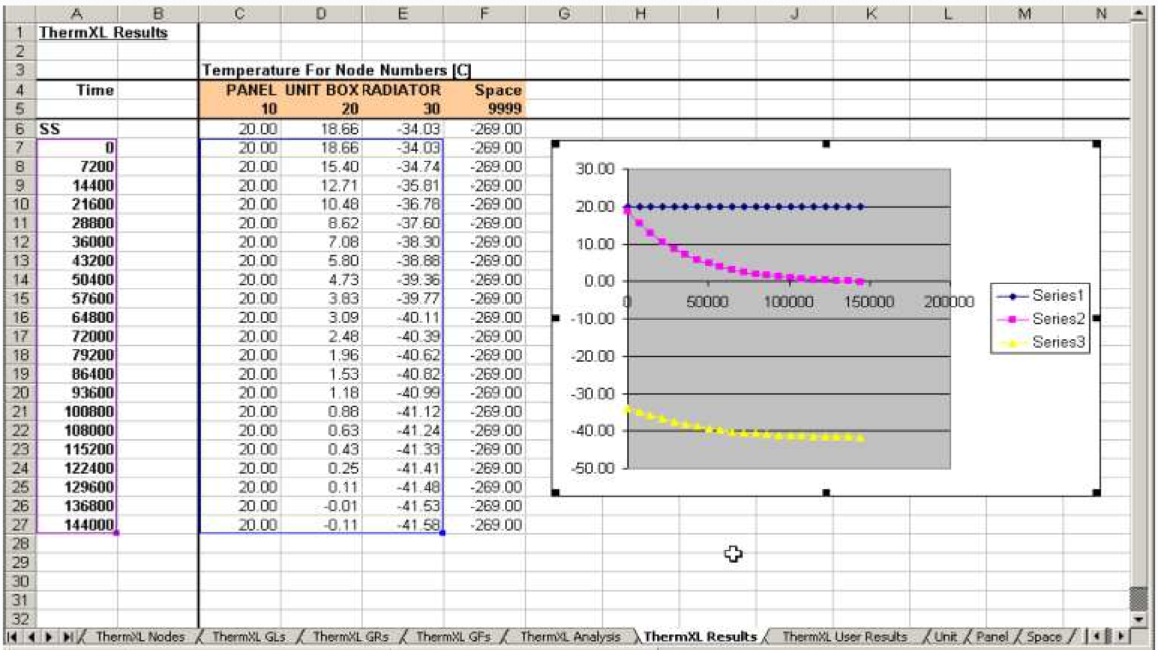
2. Run chart wizard...



- SCREENSHOT FROM LIVE DEMO -

ThermXL Overview

ALSTOM



- SCREENSHOT FROM LIVE DEMO -

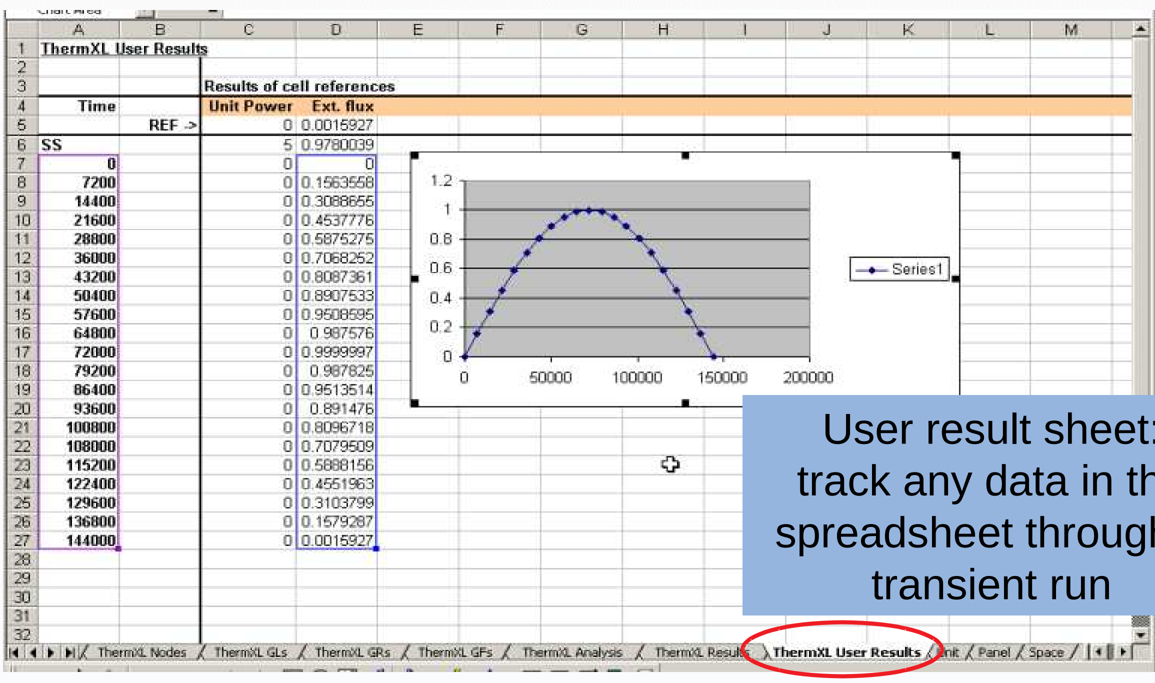
New for v2

ALSTOM

- User Defined Transient Results
- Macro access to ThermXL functions
- ESATAN & SINDA/G network export
- Node Heat Balance
- "Tidy up"
  - reformatting
  - commented control const.

ThermXL Overview

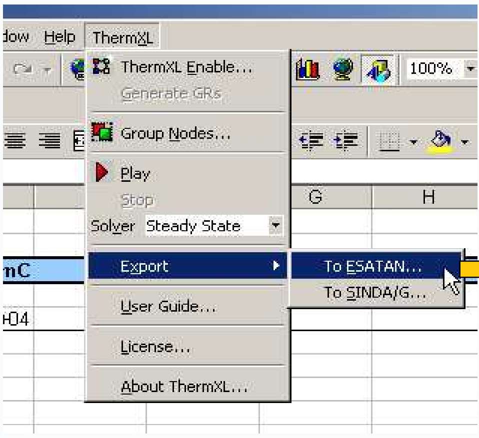
ALSTOM



	Time	Unit Power	Ext. flux
	REF ->	0	0.0015927
SS		5	0.9780039
	0	0	0
	7200	0	0.1563558
	14400	0	0.3088655
	21600	0	0.4537776
	28800	0	0.5875275
	36000	0	0.7068252
	43200	0	0.8087361
	50400	0	0.8907533
	57600	0	0.9508595
	64800	0	0.987576
	72000	0	0.9999997
	79200	0	0.987825
	86400	0	0.9513514
	93600	0	0.891476
	100800	0	0.8096718
	108000	0	0.7079509
	115200	0	0.5888156
	122400	0	0.4551963
	129600	0	0.3103799
	136800	0	0.1579287
	144000	0	0.0015927

User result sheet: track any data in the spreadsheet through a transient run

ThermXL Overview




```
# ThermXL Export File for Workshop1 (17/10/2002 17:34:37)
#
# Cells containing formulas are exported as value only
# and the content is provided as a comment.
#
$MODEL JustInCase
#
$NODES
#
B10 = 'Panel', T = 20.00;
D20 = 'Box', T = 0.00, C = 1.00e+4, QI = 5.00e+0;
D30 = 'Radiator', T = 0.00, C = 1.00e+3, QS = 2.00e+0, QA = 1.00e+0, QE = 1.00e+0;
B9999, T = -269.00;
#
$CONDUCTORS
#
GR(30, 9999) = 5.00e-2;
GL(10, 20) = 2.00e-1;
GL(20, 30) = 1.00e-1;
#
$CONSTANTS
#
$CONTROL
#
# Steady-state parameters
NLOOP = 100;
RELXCA = 1.00e+0;
DAMPT = 1.00e+0;
# Preferences
TABS = 2.731500e+2;
STEFAN = 5.670510e-8;
#
$EXECUTION
#
      CALL SOLVIT
#
$OUTPUTS
#
      FORMAT = 'E10.2'
      CALL PRQBAL(' ', CURRENT)
      CALL PRNDTB(' ', 'T,C,QS,QA,QE,QI', CURRENT)
#
$ENDMODEL JustInCase
```

- SCREENSHOT FROM LIVE DEMO -

In Development for v3

- Sensitivity Analysis
- Import of ESARAD data
- Built-in interpolation routines.
- Performance Improvements

- Ongoing Development -

Summary

ALSTOM

- Very easy to learn
- Rapid model development
- Well suited as a basis for ‘what-if’ analyses & concept development

- ThermXL v2 : Download *free* 60 day trial from:

  www.techcentreuk.power.alstom.com

- Simple, Fast Spreadsheet Analysis Tool -

ALSTOM

www.alstom.com

Appendix V: ALTAN application for Bepi-Colombo thermal analysis

**ALTAN application
for
Bepi-Colombo
thermal analysis**

V. Perotto
Alenia Spazio

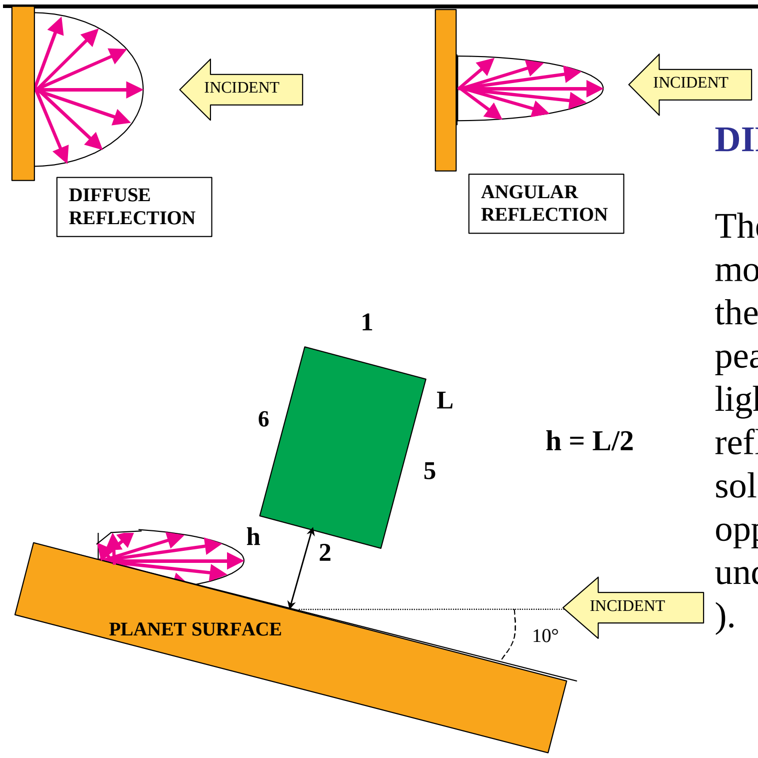
ALTAN application to Bepi-Colombo thermal analysis

V. MARESCHI, V. PEROTTO

ALENIA AEROSPAZIO - DIVISIONE SPAZIO, Thermo-Fluid-Dynamic System Department
Strada Antica di Collegno 253, 10146 TORINO (ITALY)
Tel.: +39 011 7180215 Fax : +39 011 7180239
E-mail: vperotto@to.alespazio.it

- The Bepi-Colombo mission to Mercury consists of at least two orbiters, the Mercury Magnetospheric Orbiter (MMO) and the Mercury Planetary Orbiter, a lander was also considered.
- In Mercury orbit the solar constant is from 4.5 to 9 times that on Earth, the albedo alone may correspond to a solar constant on Earth, the infrared emission of the planet is up to 10000 [W/m2]. The illuminated side of the planet may reach 700 [K], while the dark side remains at about 100 [K].
- This scenario is not easily modelled with the available radiative software, as ESARAD, THERMICA, TRASYS, THERMAL DESKTOP.
- Scope of this presentation is to identify the limits of the present thermal software, and to present a thermal software developed in ALENIA which overcomes these limits.

ALTAN application to Bepi-Colombo thermal analysis



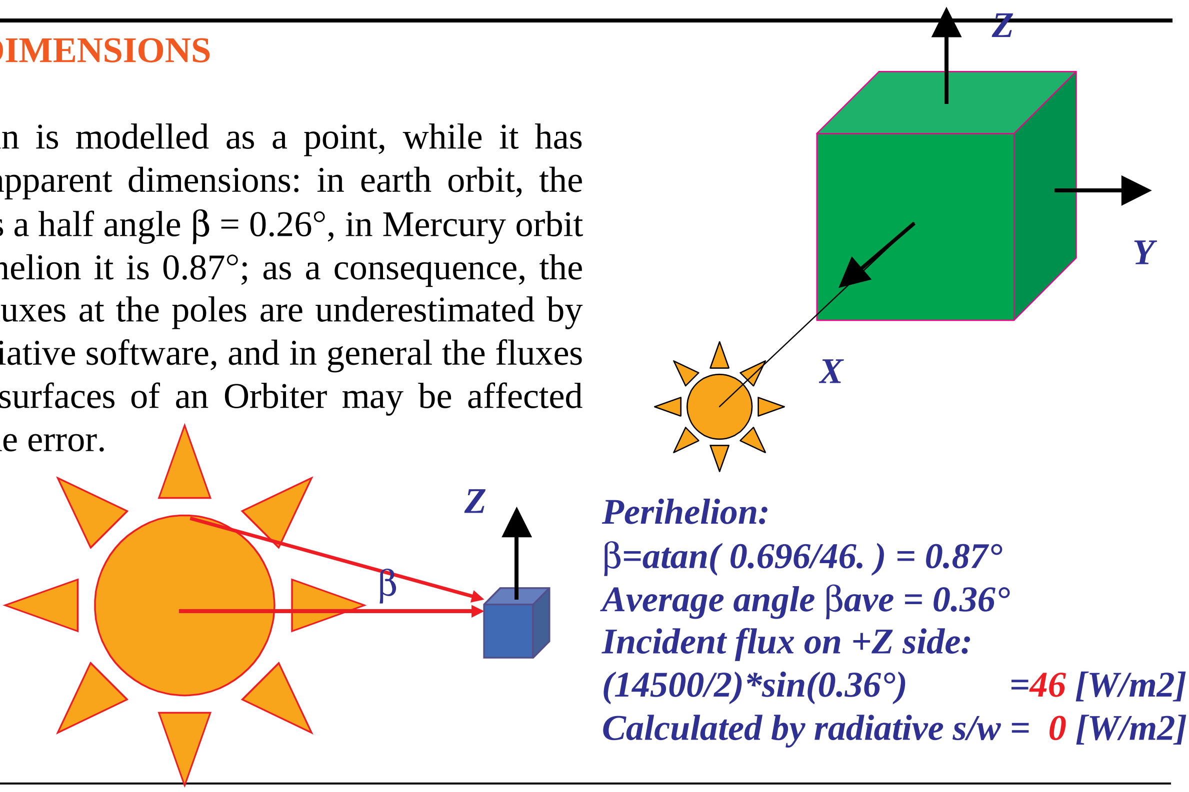
DIRECTIONAL REFLECTIVITY

The radiative software in not able to model the directional reflectivity of the planet surface, which presents a peak in the direction of the incident light; the software assumes diffuse reflectivity, as a consequence the solar fluxes reflected on surfaces opposed to the sun are underestimated (typically **30 – 50 %**).

ALTAN application to Bepi-Colombo thermal analysis

SUN DIMENSIONS

The sun is modelled as a point, while it has finite apparent dimensions: in earth orbit, the sun has a half angle β = 0.26°, in Mercury orbit at perihelion it is 0.87°; as a consequence, the solar fluxes at the poles are underestimated by the radiative software, and in general the fluxes on all surfaces of an Orbiter may be affected by some error.

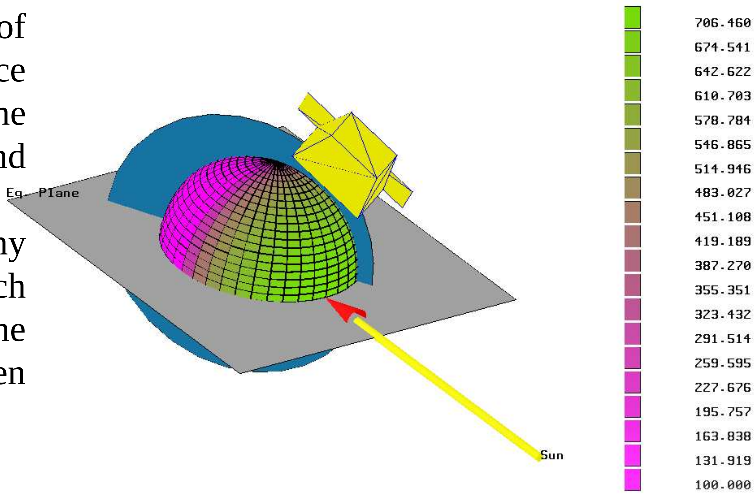


Perihelion:
β=atan(0.696/46.) = 0.87°
Average angle βave = 0.36°
Incident flux on +Z side:
*(14500/2)*sin(0.36°) =46 [W/m2]*
Calculated by radiative s/w = 0 [W/m2]

PLANET TEMPERATURE

The planet in the available thermal software is modelled as a sphere at uniform temperature. In the case of planet without athmosphere, the surface temperature and consequently the emitted energy vary with latitude and longitude.

As a consequence, the IR fluxes on any surface of a S/C depend on which portion of the planet is seen by the satellite surface. IR fluxes are then extremely variable during an orbit.



ALTAN application to Bepi-Colombo thermal analysis

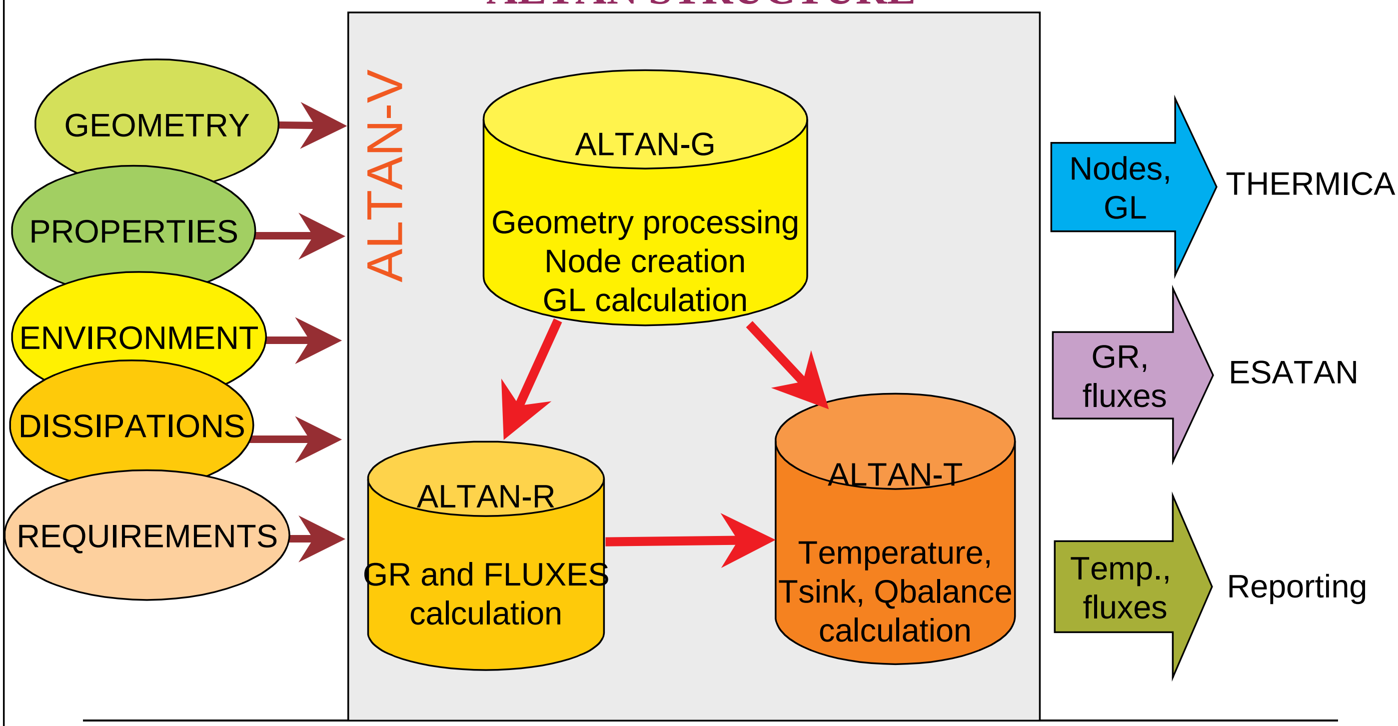
	IMPACT ON BEPI-COLOMBO THERMAL SIMULATION	SEVERITY
Planet directional reflectivity	Both the orbiters and the lander are affected. However the orbiters may benefit from the transient conditions, albedo from planet may be underestimated by the software when flying over the subsolar point, but may be overestimated in other orbital positions. In the case of a lander, the error depends on the configuration, i.e. radiator position. Several missions have flown on planets with such type of surface (Mars, the Moon), but on Mercury all thermal problems are amplified by the proximity with the sun.	3
Sun dimensions	All elements are affected, both the orbiters and the lander. Some Bepi-Colombo elements may have surfaces where the sunlight incidence angle is virtually zero. Design solution is to add some small shield to protect them.	2
Planet temperature	The orbiters are affected. Impact on the thermal design is important, additional uncertainty if planet temperature is not modelled accurately.	1

ALTAN REQUIREMENTS

To overcome the limits of the available radiative S/W, ALS has developed ALTAN, with these main requirements:

- GR calculated with ray-tracing technique;
- Simulation of directional optical properties;
- Non-uniform planet temperature;
- Two degrees of freedom for pointing;
- Complex geometries and limited boolean operations;
- GL calculation;
- Temperature calculation;
- Pre/post processing;
- Graphical User Interface;
- Interface with other thermal software;
- Runs on PC
- Based on Visual Fortran + Open GL

ALTAN STRUCTURE



ALTAN BASIC INPUT DATA

CONFIGURATION : identifies a set of thermal elements and associate them with data to locate them, to create nodes, to apply dissipations and requirements.

THERMAL PRIMITIVES (ELEMENTS) : identify a thermal / structural components defined by a geometry and properties (thermal / mass).

GEOMETRICAL PRIMITIVES: identify the geometry of a thermal primitive. They describe a SOLID, with extension and thickness. A geometrical primitive is described by:

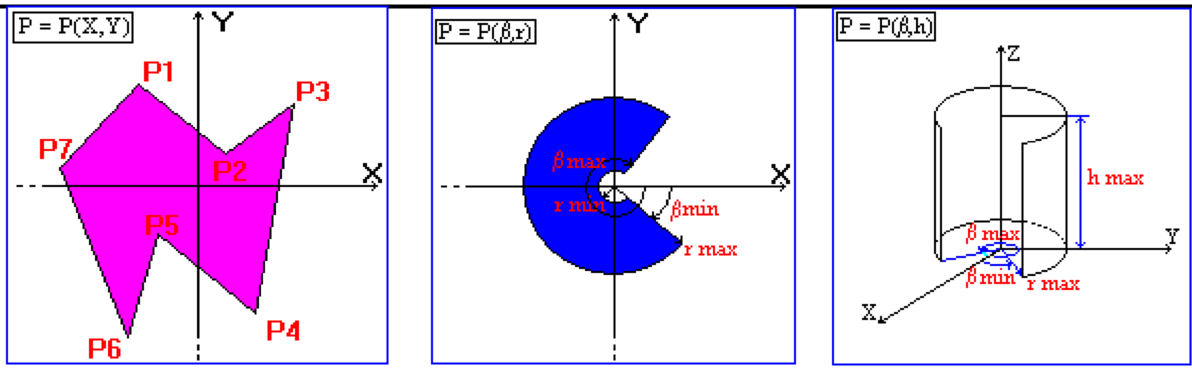
•Shape (e.g. flat, cylinder, sphere…)
•Contour (limits to the extension defined in a local surface cordinate system)
•Holes (holes through the thickness defined in a local surface cordinate system)

ALTAN application to Bepi-Colombo thermal analysis

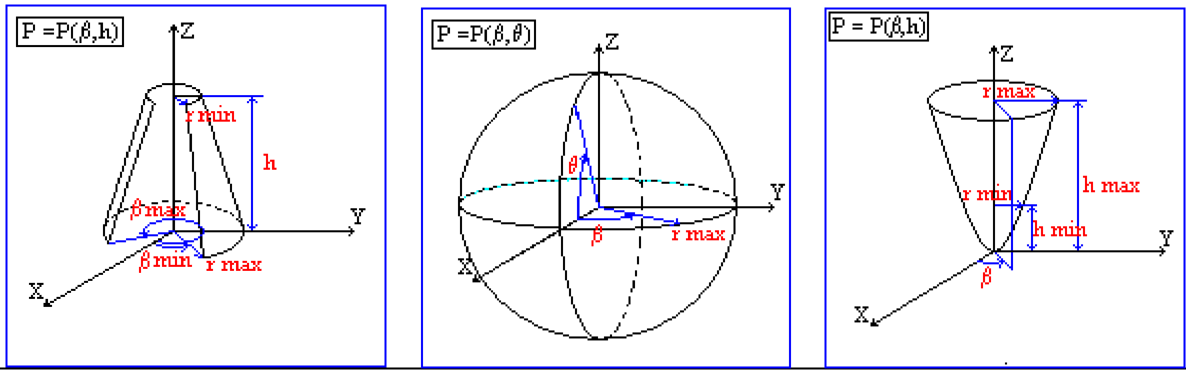
THERMAL & GEOMETRICAL PRIMITIVES

GEOMETRICAL PRIMITIVE	THERMAL ELEMENT						
	RADIATOR	EQUIPMENT		MLI	DOUBLER	HEAT PIPE	TUBE
		Cover	Base				
polygon	X	X	X	X	X		
disk	X	X	X	X	X		
cylinder	X	X		X	X		
cone	X	X		X	X		
sphere	X	X		X	X		
paraboloid	X	X		X	X		
revol1	X			X	X		
revol2	X			X	X		
extruded	X			X	X	X	X

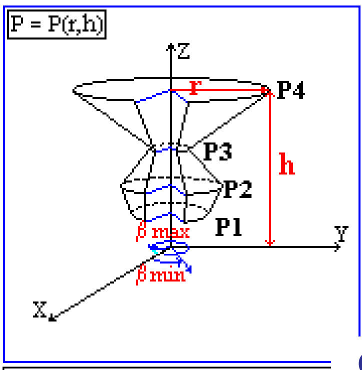
ALTAN application to Bepi-Colombo thermal analysis

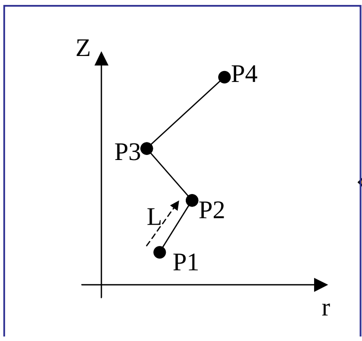


GEOMETRICAL PRIMITIVES



ALTAN application to Bepi-Colombo thermal analysis





Revol1, Revol2 Define:

- A curve **C** of N points in a local ref. (r,Z)
- β_{min}, β_{max} (Revol1) or **N** steps (Revol2)

Revol1 is defined by rotating **C**, generating portions of disk, cylinder and cones

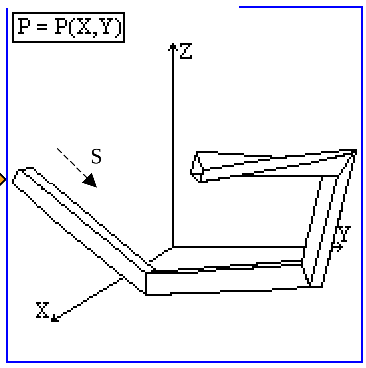
Revol2 is defined by rotating **C** by **N** steps and by joining the vertices of the resulting curves, generating flat surfaces (pyramid…)

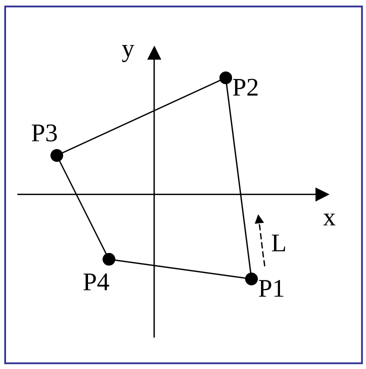
GEOMETRICAL PRIMITIVES

Extruded Define:

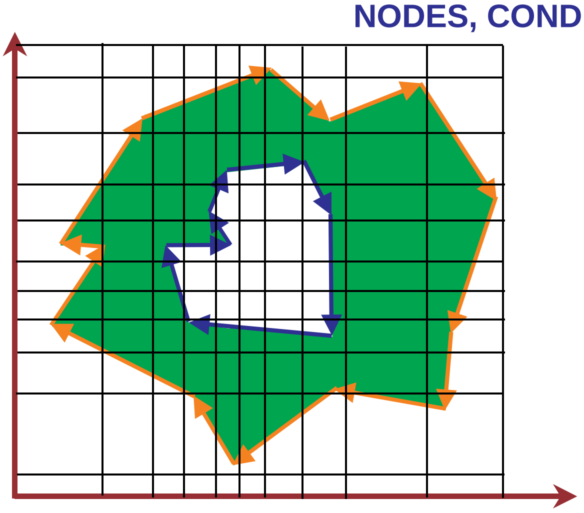
- A curve **C** of N points in a local ref. (x,y)
- A line **S** of M punti in (x,y,z)
- A vector ***V*** nello spazio (x,y,z) for each point M

The surface is defined by transporting the curve **C** along the line **S**, and by rotating **C** to keep its local x parallel to ***V***





NODES, CONDUCTORS & TEMPERATURES



Nodes are generated by applying a grid to the geometrical primitive

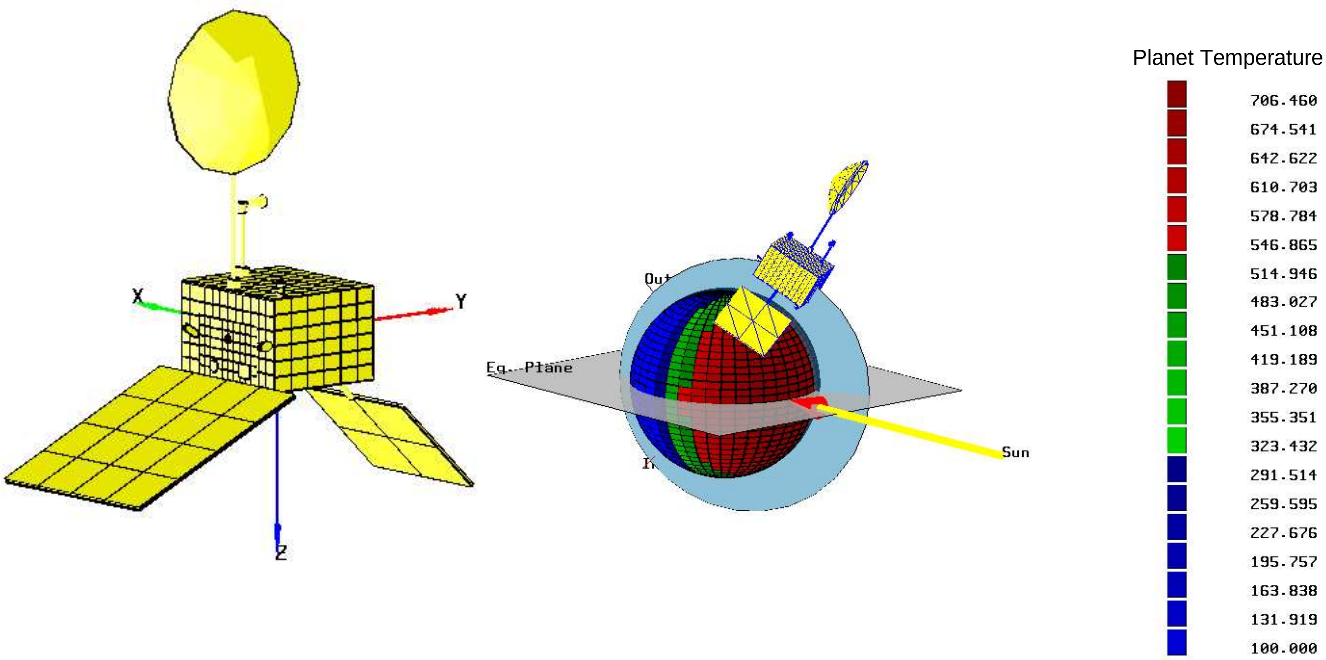
GL are calculated by extension of typical formula K*area/distance

GR and orbital fluxes are calculated with MonteCarlo ray tracing.

Temperatures for steady state and transient are calculated by traditional methods (as ESATAN routines SOLVIT and SLFWBK)

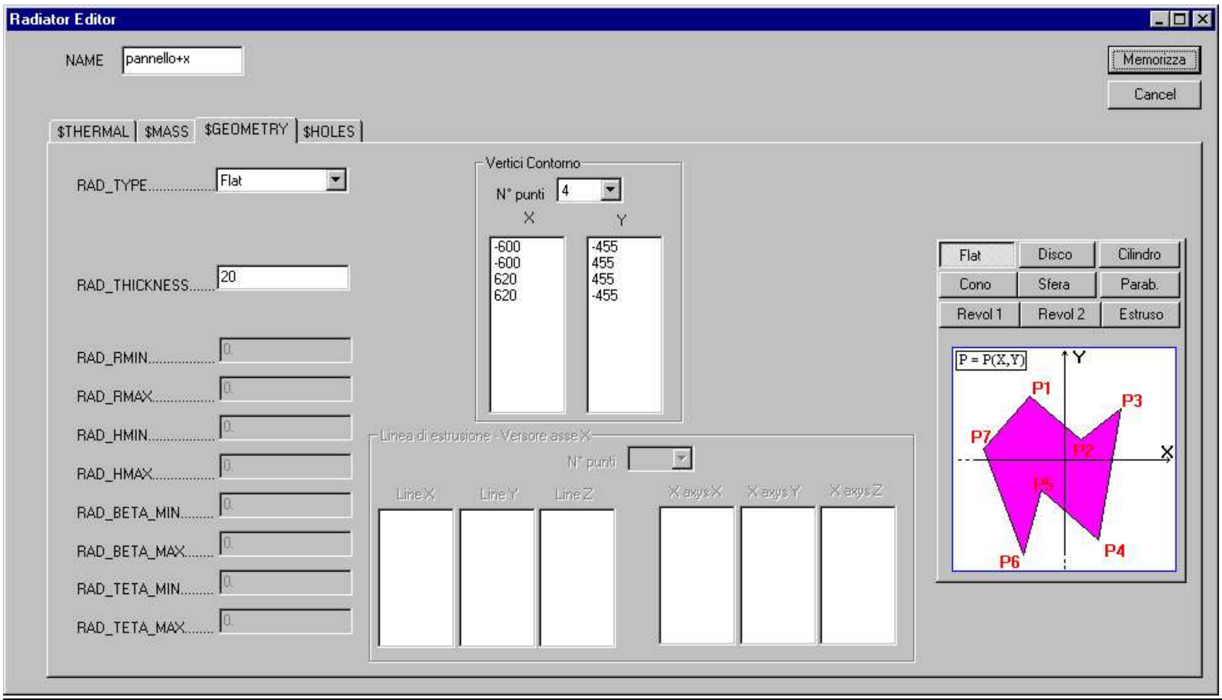
Alenia SPAZIO A FINMECCANICA COMPANY
ALTAN application to Bepi-Colombo thermal analysis

VISUALIZATION



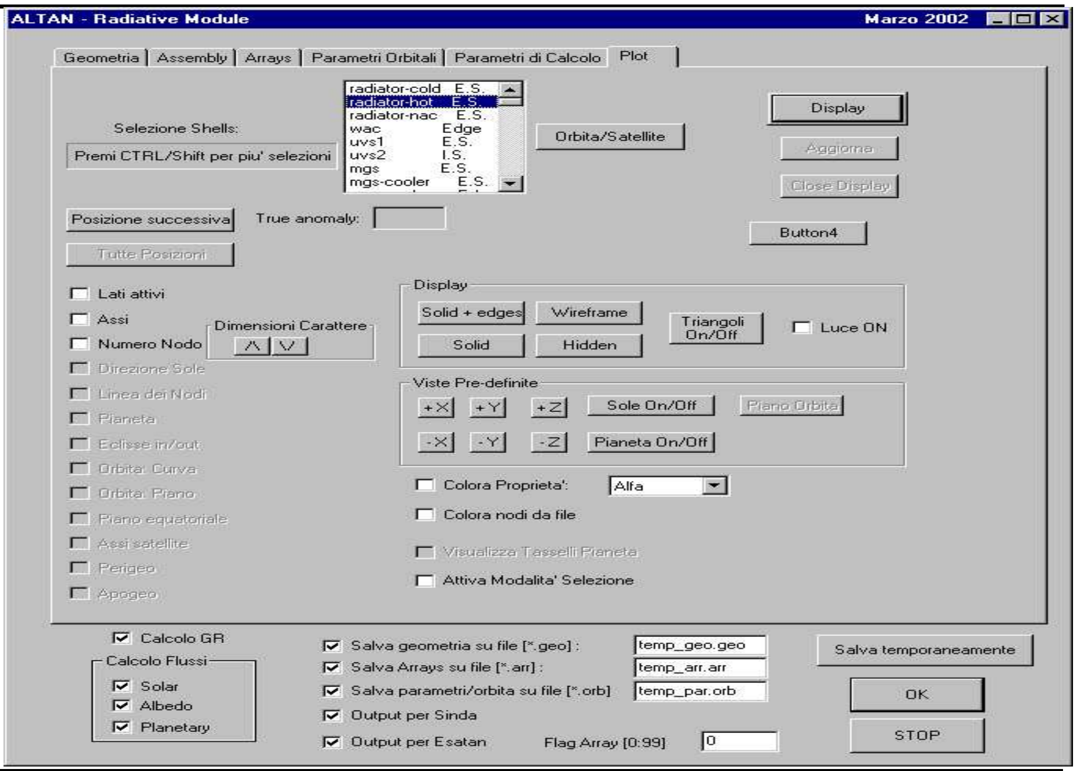
ALTAN application to Bepi-Colombo thermal analysis

USER INTERFACE

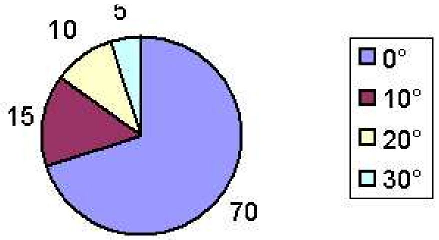


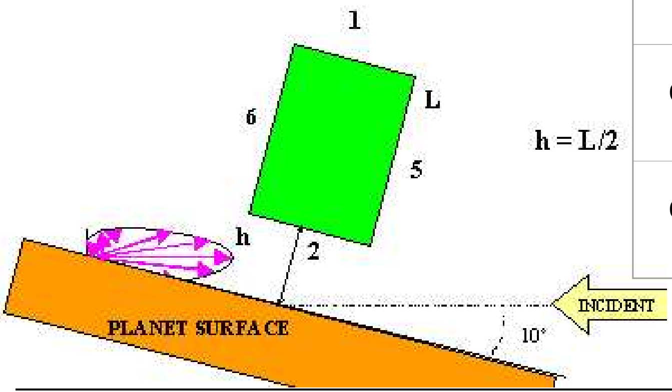
ALTAN application to Bepi-Colombo thermal analysis

USER INTERFACE



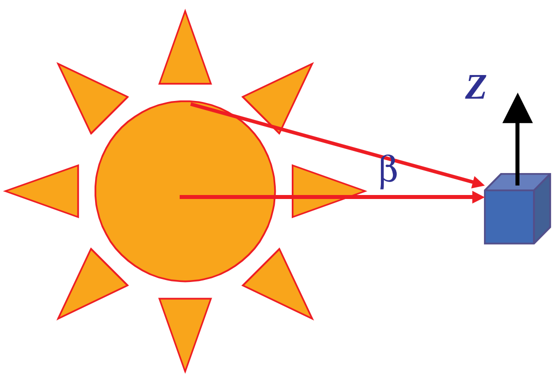
PLANET SURFACE ANGULAR REFLECTIVITY





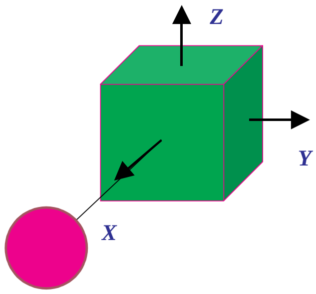
Planet reflection & radiative S/W	INCIDENT SOLAR FLUX [W]					
	side 1	side 2	side 3	side 4	Side 5	side 6
Diffusive (THERMICA)	1692	329	114	115	9706	128
Diffusive (ALTAN)	1691	332	113	113	9703	127
Angular (ALTAN)	1692	72	20	21	9685	161

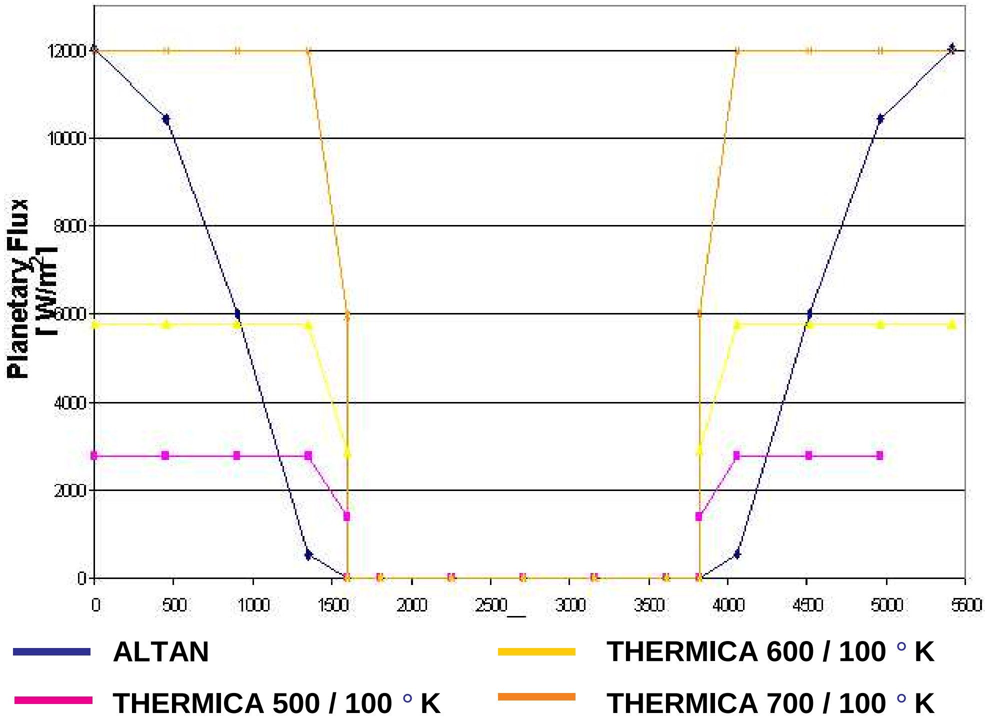
SUN DIMENSIONS



Radiative S/W	INCIDENT SOLAR FLUX [W]	
	+Z	+X
THERMICA	0	14383
ESARAD	0	14383
TRASYS	46	14387
ALTAN	47	14381

PLANET TEMPERATURE





CONCLUSIONS

MISSIONS AS LEDA-LUNISS AND BEPI-COLOMBO HAVE REVEALED THE LIMITS OF THE COMMERCIAL RADIATIVE THERMAL S/W;

REQUESTS TO IMPROVE COMMERCIAL RADIATIVE S/W HAVE BEEN FREQUENTLY RAISED IN THE PAST YEARS BUT PROGRESS HAS BEEN INSUFFICIENT;

IN-HOUSE DEVELOPED S/W HAS BEEN NECESSARY, DRAWBACKS: COSTS, PROLIFERATION OF TOOLS, LOSS OF COMMON BASE;

SUGGESTION:
IMPROVEMENT OF COMMERCIAL S/W;
SUPPORT DEVELOPMENT OF INTERFACES TO STEP;

Appendix W: Last developments in and around GAETAN

Last developments
in and around
GAETAN

C. Marechal
CNES

LAST DEVELOPMENTS IN AND AROUND GAETAN

« Global Analysis Environment for Thermal Analysis Network »

Ch. Maréchal

CNES
Thermal Control Department - Bpi 1416
18,avenue Edouard Belin
31401 Toulouse Cedex 4

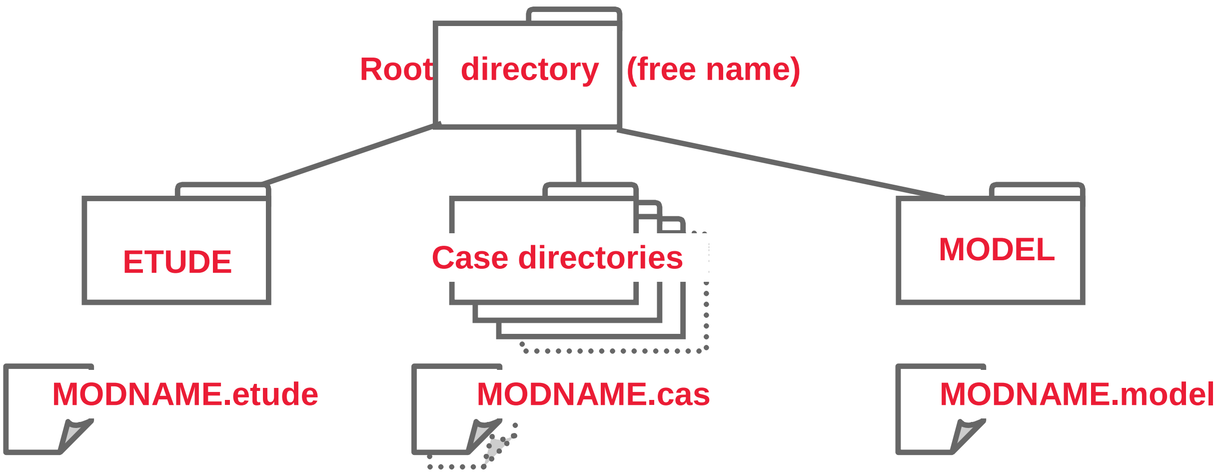
Summary

- ***Introduction***
- ***New functions for thermal study management***
  - ***Thermal study management principle***
  - ***Thermal coupling cases analyses***
  - ***Thermal sensitivity analyses***
- ***Thermal model configuration management***
- ***GAETAN I/F with thermal radiative tools (CONDOR , ESARAD)***
- ***Future developments***

Introduction

- *GAETAN V5.2*
- *Environment for thermal analyses*
  - *Based on lumped parameter method (i.e. ESATAN)*
  - *Based on thermal budget analyses*
  - *Many prepro and postprocessing features*
- *Developed since 1996*
- *Harmonized with ESTEC (Use of & I/F with ESATAN - FHTS (in progress) - ESARAD)*
- *5 french industrial sites + CNES*
- *CNES licenses for use and development*
- *Development & maintenance done by Silogic (F.)*

Thermal study management principle



1 « Study » file
- All options for the study
- Description of each case

1 case file per directory
- Calls the case to run and
its specific analyses
- Results

Only 1 model
+ included files

Thermal coupling cases analyses
What is the problem ?

- **GAETAN principle**
  - ONE thermal model for ALL load cases
- **Difficult to include several values for one coupling in ESATAN models**
  - manual edition
  - use of ESARAD variable geometry
  - ESARAD outputs do not allow several sets of radiative couplings in one model
- **Example**

Thermal coupling cases analyses
Example of problem

1st case of GEOMETRY

ESARAD output :

$CONDUCTORS
GR(6,5) = 0.00002 ;

2nd case of GEOMETRY

ESARAD output :

$CONDUCTORS
GR(6,5) = 0.00005 ;

Direct $INCLUDE in same MODEL = ERROR or bad values !

!  !

SOLUTION : CONDITIONNAL INCLUDE AS A FONCTION OF A VARIABLE

Thermal coupling cases analyses Principle

In the Study file

```
….
$CHARGE_CASES_DEFINITIONS
       @NEW_CHARGE_CASE_DEFINITION
              CHARGE_CASE_NAME =             'CD FORT';
                     EXTERNAL_FLUXES_CASE =       'EOL';
                     COUPLING_CASE =              'CACOUP = fort';

       @NEW_CHARGE_CASE_DEFINITION
              CHARGE_CASE_NAME =             'CD FAIBLE';
                     EXTERNAL_FLUXES_CASE =       'EOL';
                     COUPLING_CASE =              'CACOUP= faible';
….
```

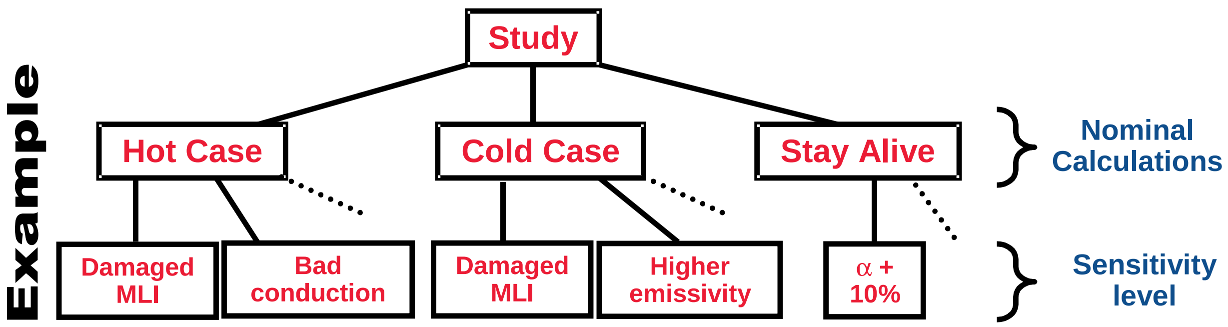
In the Model (or included) file

Included only if variable « CACOUP » is equal to ‘ fort ’

```
...
#READ conductif.1        :: CACOUP = 'fort'
#READ conductif.2        :: CACOUP = 'faible '
...
```


Thermal sensitivity analyses Principle

- ***Each “nominal” case gets sensitivity cases***
- ***Sensitivity cases are automatically :***
  - *Calculated,*
  - *Analysed*
  - *Archived in the comparison database*
  - *Compared to their nominal case*



Thermal sensitivity analyses
Example of input

```
$CHARGE_CASES_DEFINITIONS
       @NEW_CHARGE_CASE_DEFINITION
              CHARGE_CASE_NAME =                      'NOMINAL';
                     EXTERNAL_FLUXES_CASE =                  'TOTO';
                     SENSITIVITY_CASE = 'COUPCA = fort';
                     SENSITIVITY_CASE = 'CASRAD = fort';
                     EXTERNAL_FLUXES_SENSITIVITY_NAME = 'test';
                     EXTERNAL_FLUXES_ENTITIES_LIST =         'QS' ;
                     EXTERNAL_FLUXES_MULTIPLICATIVE_FACTORS = '0.5' ;
[. . .]

$THERMAL_RESULTS_COMPARISON
       @GENERAL_OPTIONS
              NODES_SELECTION =            '140,160,200' ;
              THERMAL_SPECIFICATIONS_CASE_NAME = 'nominal' ;

       @SENSITIVITY_COMPARISON
              CURRENT_CALCULATION_CASE =        'NOMINAL' ;
              TO_COMPARE_WITH          =        'COUPCA=fort' ;

       @NODES_TEMPERATURE_LEVELS
       @HEATERS_CONSUMPTIONS
       @BOUNDARY_FLUXES
```


Thermal sensitivity analyses
Example of model programming

```
[...]

$CONDUCTORS

  GR(10,20) = 0.0002 * VAR ;

  #READ conductif.fort  :: COUPCA = 'fort ’

[...]

$INITIAL

       IF (CASRAD .EQ. ‘fort ’) then
          VAR = 1.2
       ENDIF

[...]
```

Thermal sensitivity analyses Example of result file

```
===================================================
Comparaisons multi-cas avec le cas de specification:  nominal
Cas de calcul compares:                             NOMINAL   NOMINAL    NOMINAL    NOMINAL
Code caractère du calcul:                              A         B          C          D
Code de sensibilite:                                  none  CASRAD=fort COUPCA=fort EXT_F=test
 ===================================================

        ======================================================================
        Edition des temperatures soumises a specification avec marge de calcul
        ======================================================================
NOEUD       LABEL         Perf.basse(C) Perf.haute(C) Tmin(C) Tmax(C) Ecart/min(C) Ecart/max(C)
SENSI:140   Diffus froid       6.90 B       57.88 C    -80.00   150.00     86.90      102.12
SENSI:160   Diffus chaud      65.48 A       89.71 C    -10.00              75.48

        =====================================================================
        Edition des pentes de temperature soumises a specification avec marge
        =====================================================================
NOEUD        LABEL                 Perf.haute(C/s ) Pente max(C/s )   Ecart/max(C/s )
SENSI:140    Diffus froid              -7.56 B          0.09              7.65     HORS MARGES

        ========================================================================
        Edition des flux d'interface soumis a specification avec marge de calcul
        ========================================================================
NOEUD          LABEL                       Perf.haute(W )   Puiss.max(W )  Ecart/max(W )
SENSI:200      Environnement chaud             -6.73 C        3000.00         3006.73
```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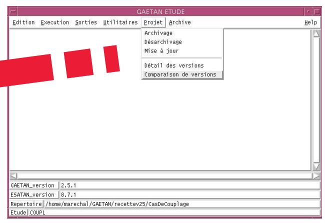
Thermal model configuration management



Drop a new version of the TMM in the archive

Get back to a previous version of the TMM

Make the last archived version of the TMM « up to date »

Get the orginal version number of each files of an archived version of the model

Compare archived versions

16th European Thermal & ECLS Software Workshop - 22-23 October 2002- Noordwijk, NL

Thermal model configuration management

- ***Based on CVS (Configuration management freeware)***
- ***As simple as possible***
  - *Basic functions*
  - *Only through GAETAN IHM*
- ***Each archived version gets***
  - *A number (1, 2 …) (no 1.1 , 1.2 ...)*
  - *An archive date*

CONDOR

- ***Software for efficient evaluation of external orbital conditions :***
  - *Solar / Albedo / Planetary fluxes chained calculations : search of thermal dimensionning cases*
  - *Sucess criteria based on any type of CONDOR but also GAETAN / ESATAN results : fluxes, T°, DT, DT/Dt, min / max, heating power, a.s.o. ...*
- ***Not part of GAETAN***
- ***CNES internal tool***
- ***CONDOR can drive GAETAN (ESATAN / FHTS) and ESARAD***

CONDOR - Geometry

- Cube
- Plate 2 sides (1mx1m)
- Cylinder
- Sphere
- Solar panel
  - Solar pointing
- Any ESARAD Geometry
  - if so, CONDOR runs ESARAD

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CONDOR - Orbit

- Geostationnary
- Heliosynchronous
- Polar
- Circular
- Elliptical
- Tabulated (Time and position tabulated)

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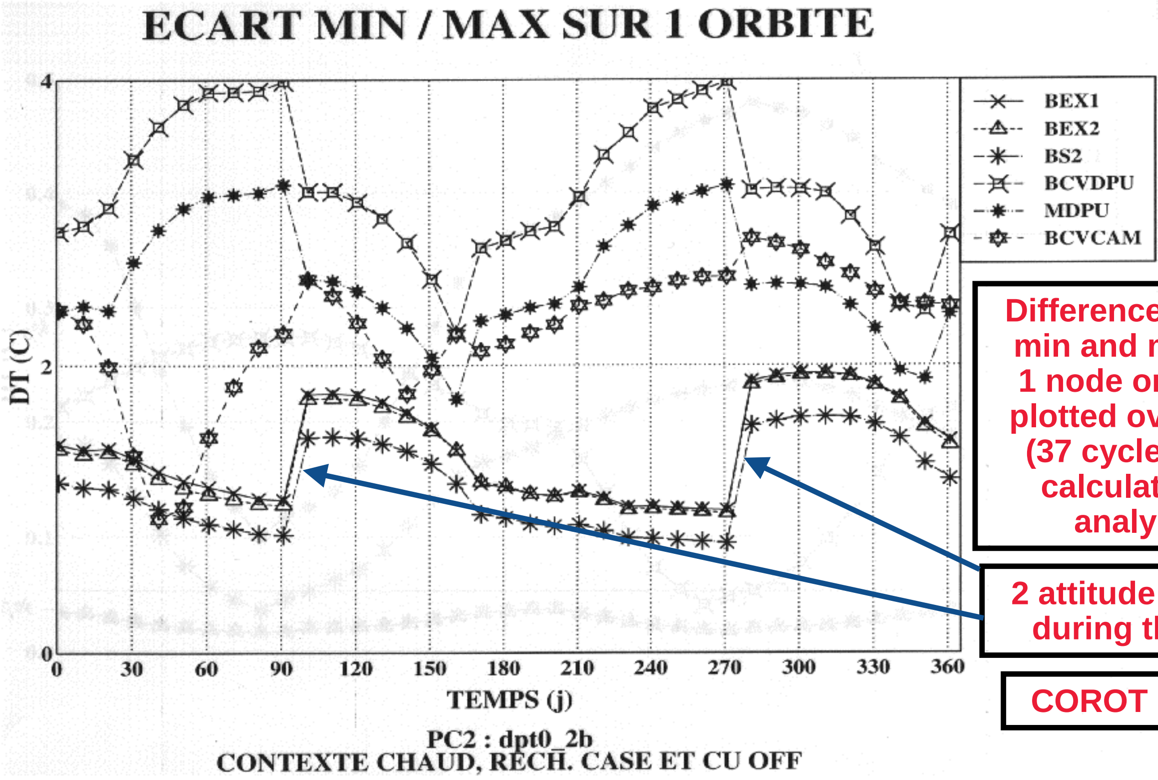
CONDOR - Attitude

- *Geocentric reference frame*
- *Inertial reference frame*
- *Solar reference frame*
- *Tabulated (Time vs attitude quaternions in inertial equatorial reference frame)*

CONDOR - General

- *Outputs*
  - *External fluxes and radiative sink temperatures*
    - » *Over any orbit*
    - » *Any orbit : Orbital average over a year*
- *Very easy attitude and orbit definition*
  - *Input parameters depend on type of orbit and attitude*
- *If the TMM exists*
  - *CONDOR launches the temperature calculations*
  - *On each chosen day of the year*
  - *Launches GAETAN analyses for comparison of the any results (T°, DT, dT/dt, DT/(t1-t2), min/max, heating power, fluxes, boundary fluxes, a.s.o. ...)*
- *Very powerful tool to find dimensionning cases*

CONDOR : Example



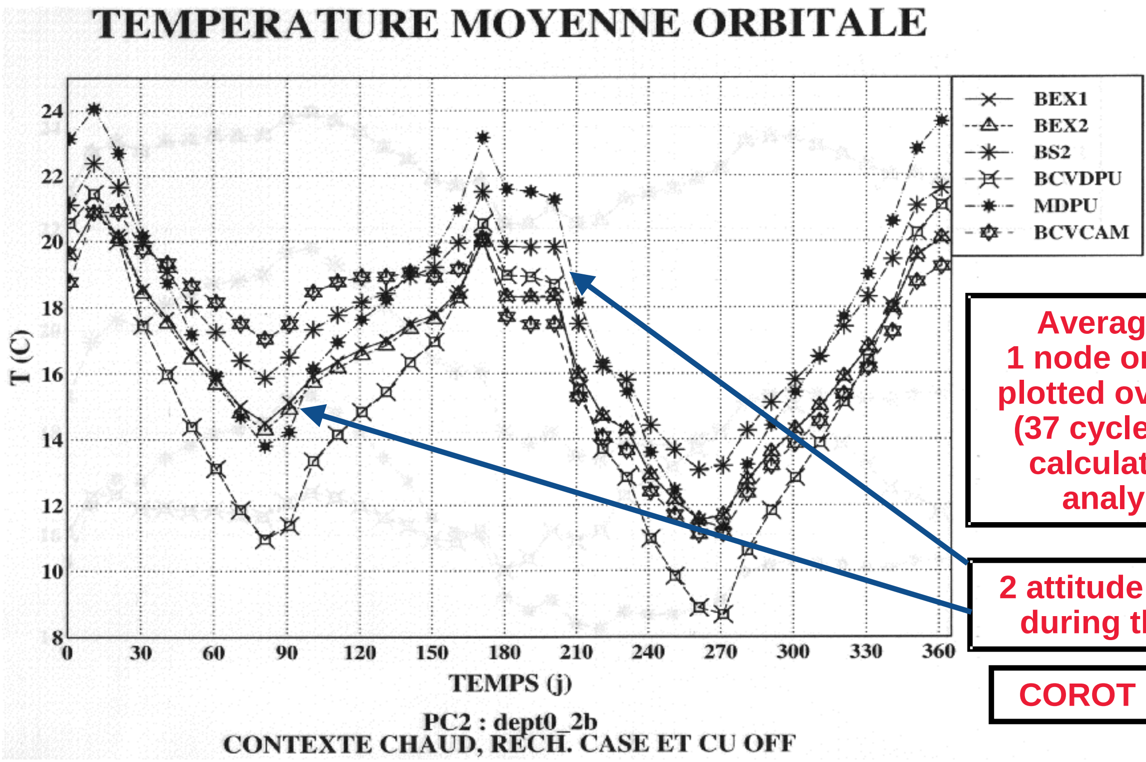
Difference between min and max T° of 1 node on 1 orbit, plotted over 1 year (37 cycled orbits calculated and analysed)

2 attitude changes during the year

COROT Project

Division Mécanique Thermique Energétique - Octobre 2002

CONDOR : Example



Average T° of 1 node on 1 orbit, plotted over 1 year (37 cycled orbits calculated and analysed)

2 attitude changes during the year

COROT Project

16th European Thermal & ECLS Software Workshop - 22-23 October 2002- Noordwijk, NL

Future developments

- GAETAN compatibility with FHTS (To 10/2002)
  - Management of fluidic entities
  - Power budget calculations
  - Simplified mass and volume budgets
- Semi-automatic thermal model reduction - Energetic method (mid-2003)
- IHM and command language for CONDOR

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Appendix X: CAD-FE integration using Open Source Software

CAD-FE integration
using
Open Source Software

C. Caillet
OpenCASCADE

CAD-FE integration

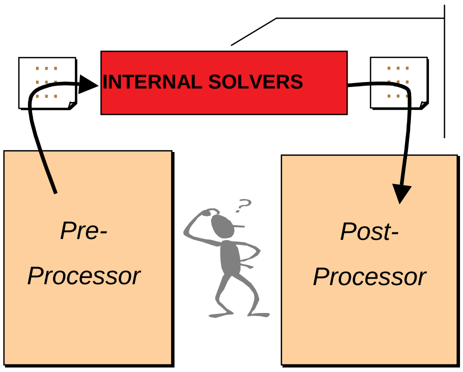
using Open Source Software

Christian Caillet

c-caillet@opencascade.com

1st need : «multi-physics»

Research Center

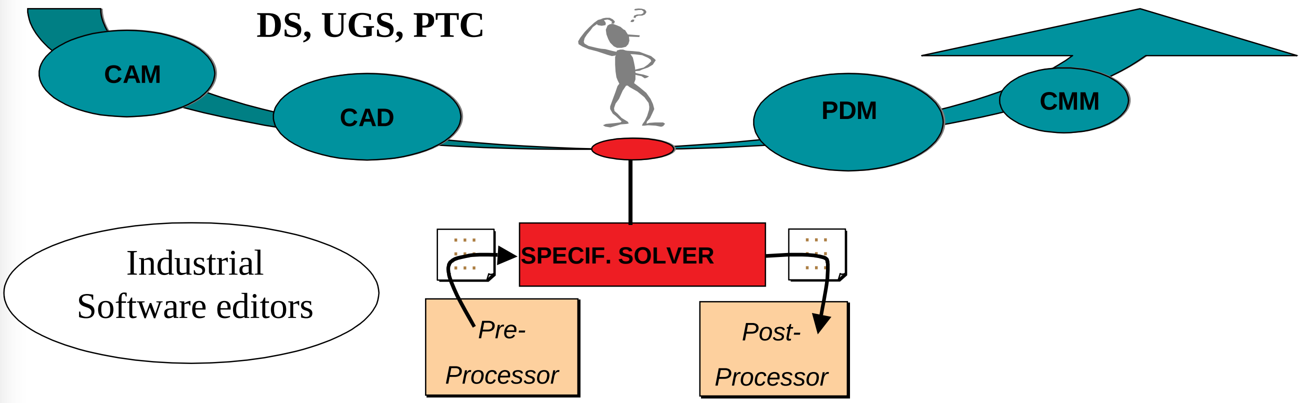


- Strategic
- high level of Innovation
- Large investment

- **To improve efficiency**
  - → Time request to build data card ?
- **To simplify multi-physics**
  - → Computation schema ?
- **To simplify user training**
  - → User friendly ?

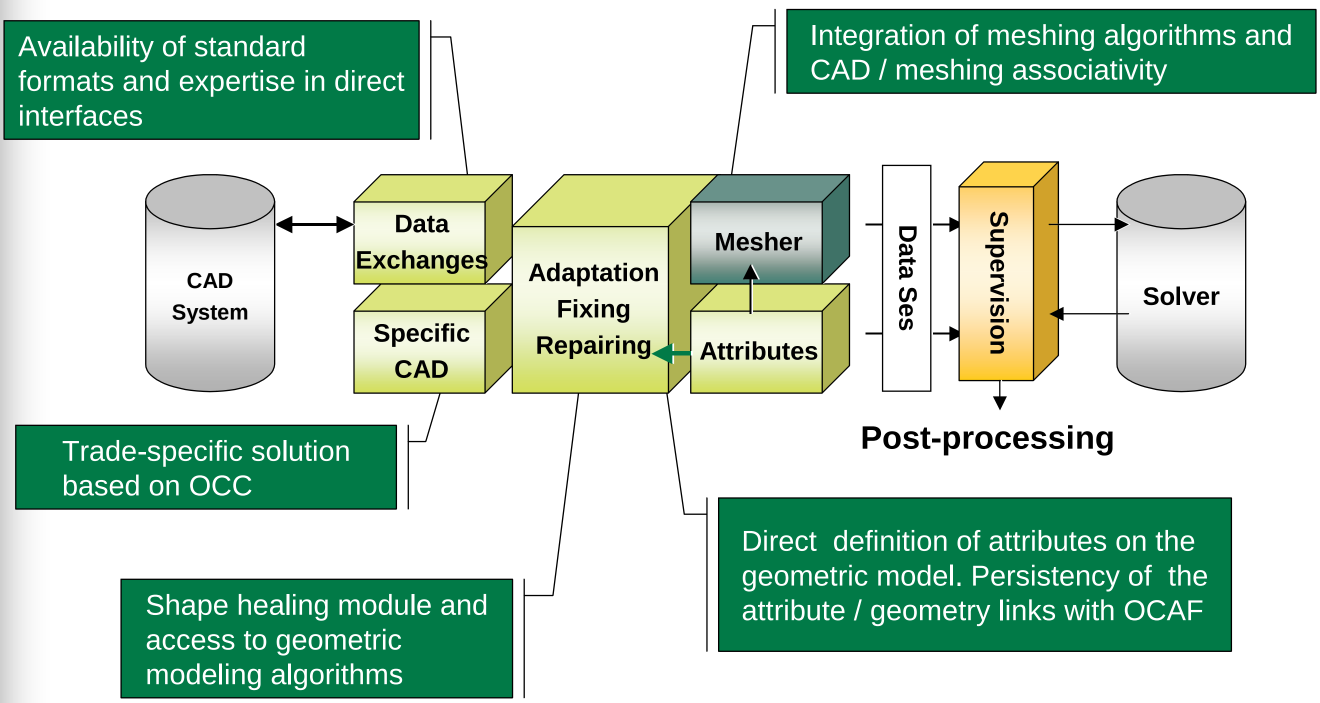
To focus R&D on the core competency
Optimize the investment

2nd need : « more simulation »



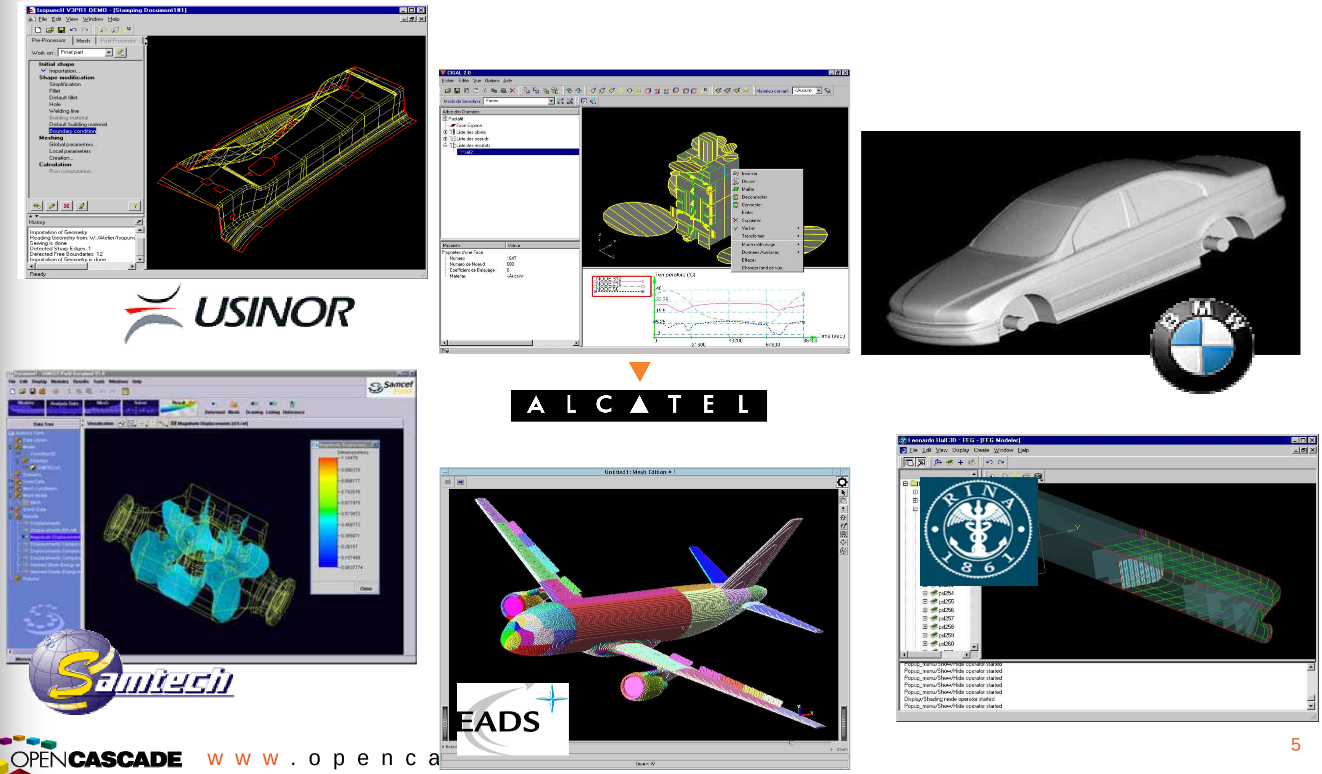
- **Specific simulation solution within standard CAD solutions**
  - → Efficient Pre/Post processor
  - → Mesh for CAD solution
  - → Simulation data within PDM system

CAD / FE optimized integration

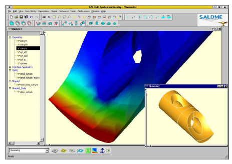


CAD-FE INTEGRATION REFERENCES

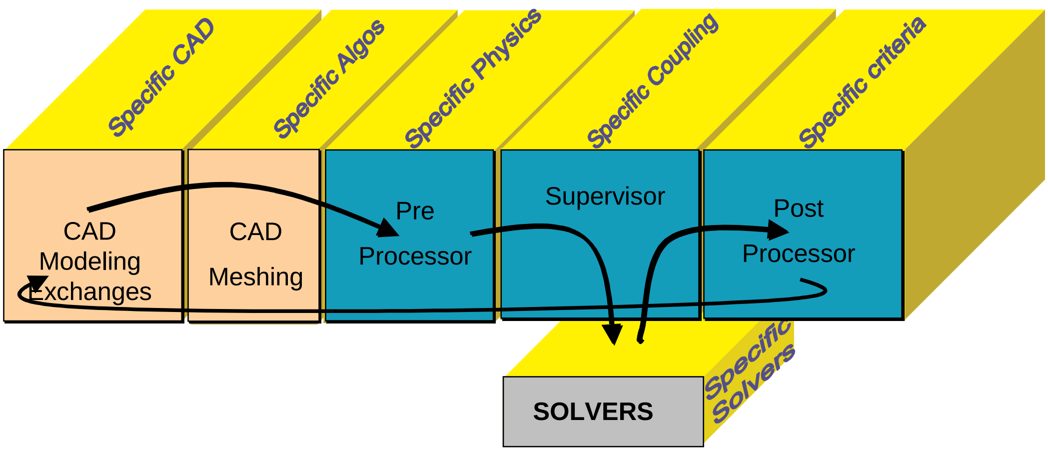
Industrial projects achieved, based on Open Source Software



SALOME



Open Source CAD-FE integration platform to build specific simulation solutions



SALOME Platform

TECHNICAL CHOICES

- **Standards adoption**
  - Operating system
  - Software architecture
  - CAD data interface

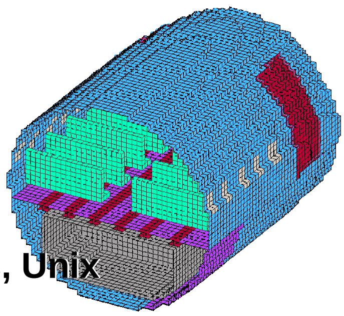
CORBA

STEP Iges

- **Open Source adoption**
  - *http://www.opencascade.org*
  - re-use of approval Open Source component :

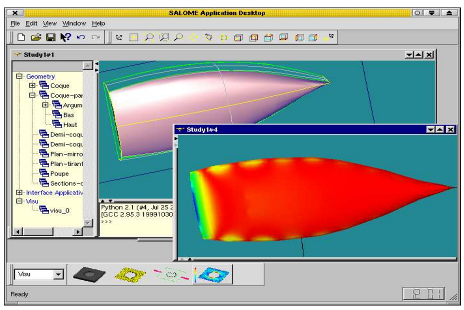
SALOME Platform

DEVELOPMENT CONSTRAINTS

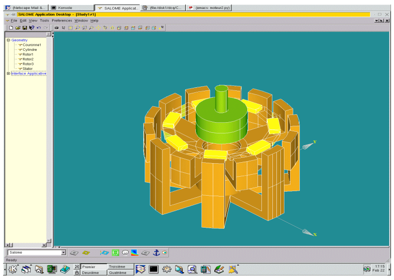


- **Portable**
  - **Portable source code**
  - **Support of Linux (development), Windows, Unix**

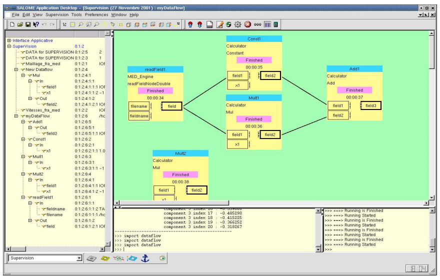
- **User friendly**
  - **Look&Feel**
  - **Heavy model**
  - **component approach**

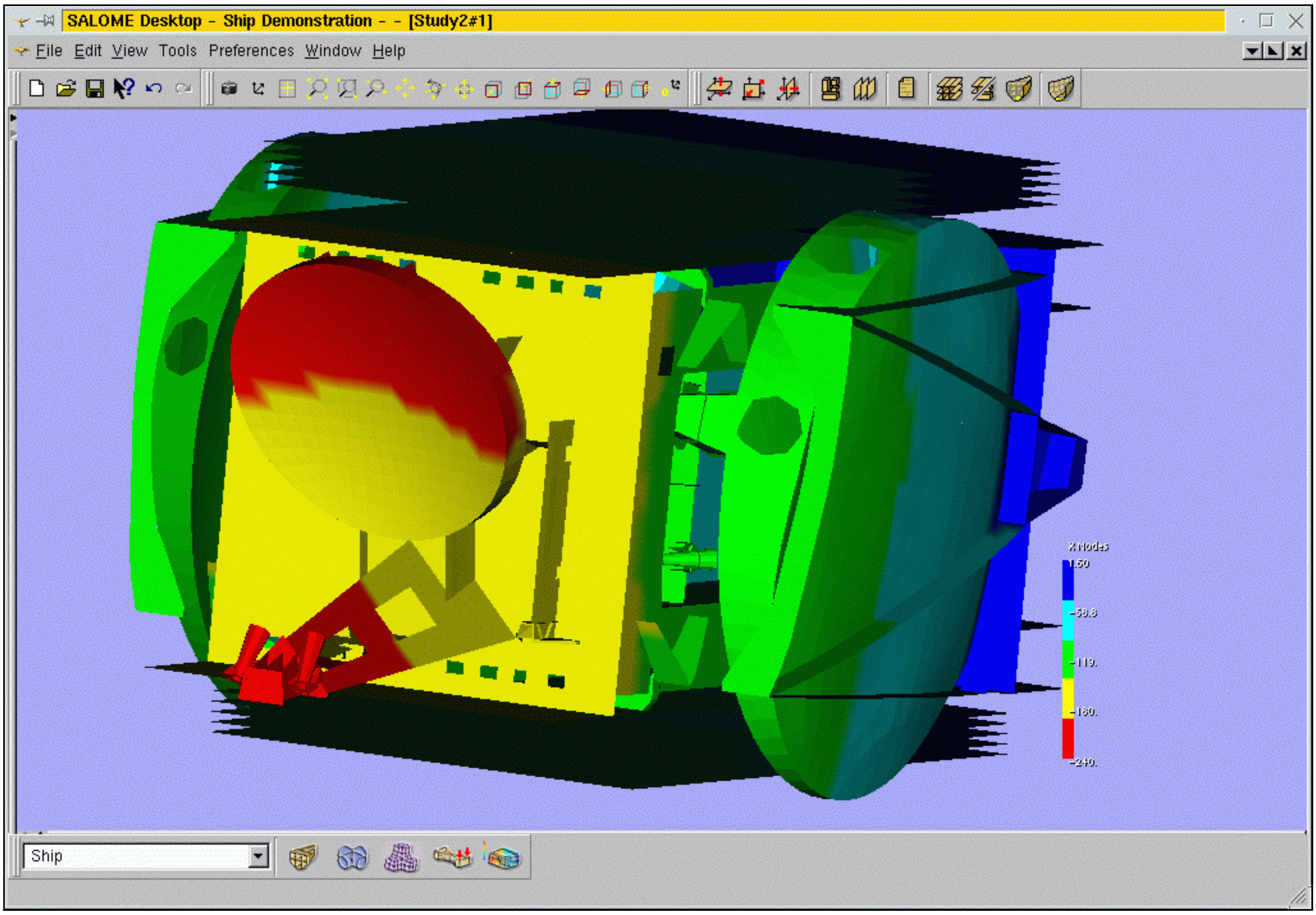


2 MAIN FEATURES

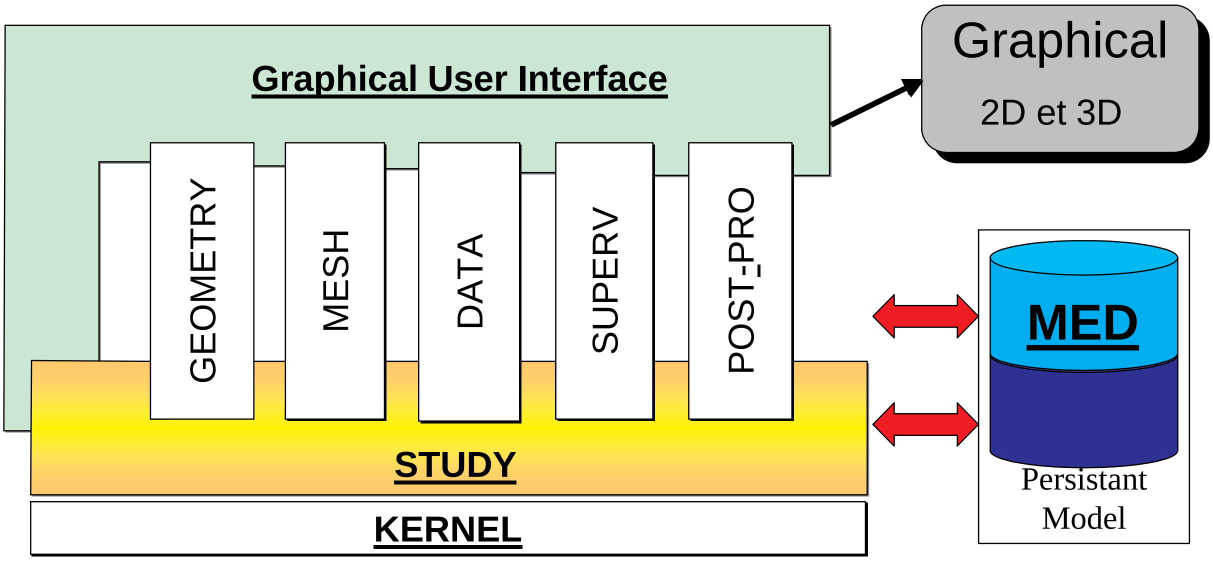


- **CAD-FE Integration**
  - CAD interface and Correction
  - Idealization of CAD Model
  - Basic CAD modeling features
  - CAD-MESH associativity
  - FE properties assigned on CAD model
- **Coupled/Multi-physics problems**
  - Same user interface
  - Computational schema
  - Distributed computation
  - Exchange format (MED)





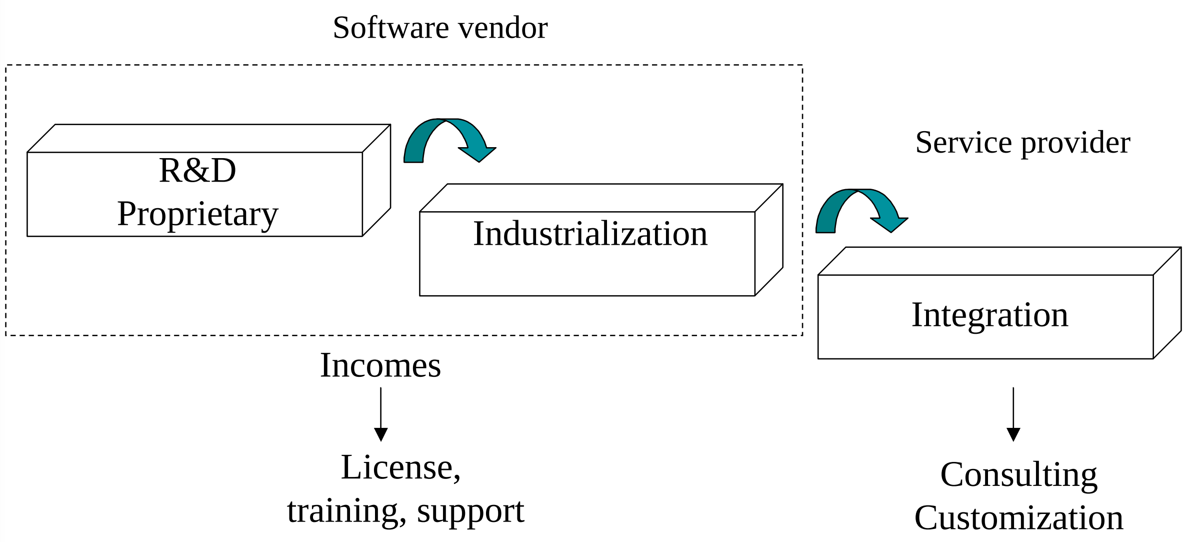
SOFTWARE ARCHITECTURE



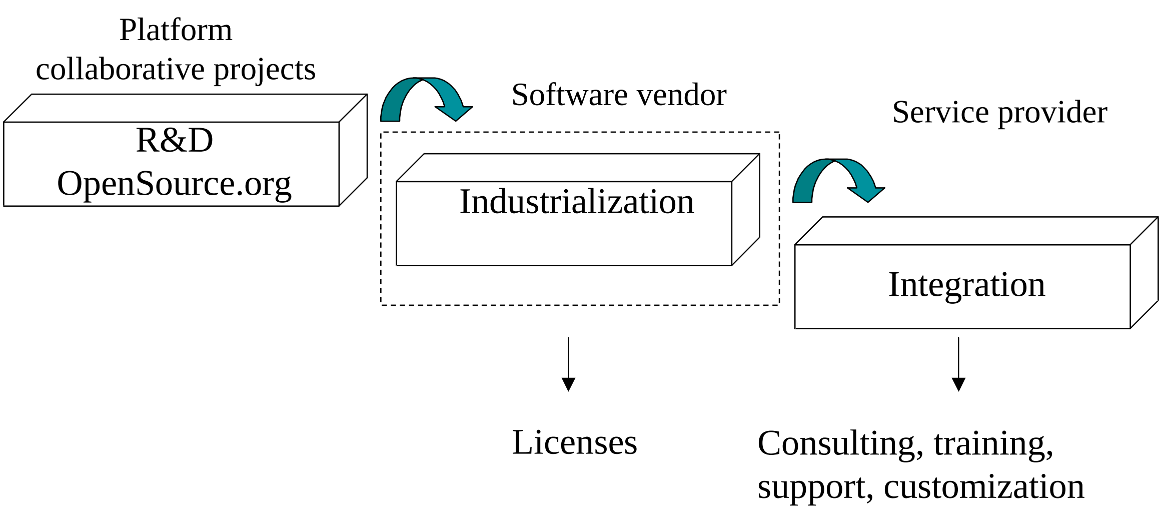
EFFORT ENGAGED

- **Know-how of 9 partners**
- **Resources / 2 years (Sept-2000, Sept-2002)**
  - **540 man.months**
  - **Around 50 people**
- **Has received RNTL label**

TRADITIONAL IT DEVELOPMENT PROCESS

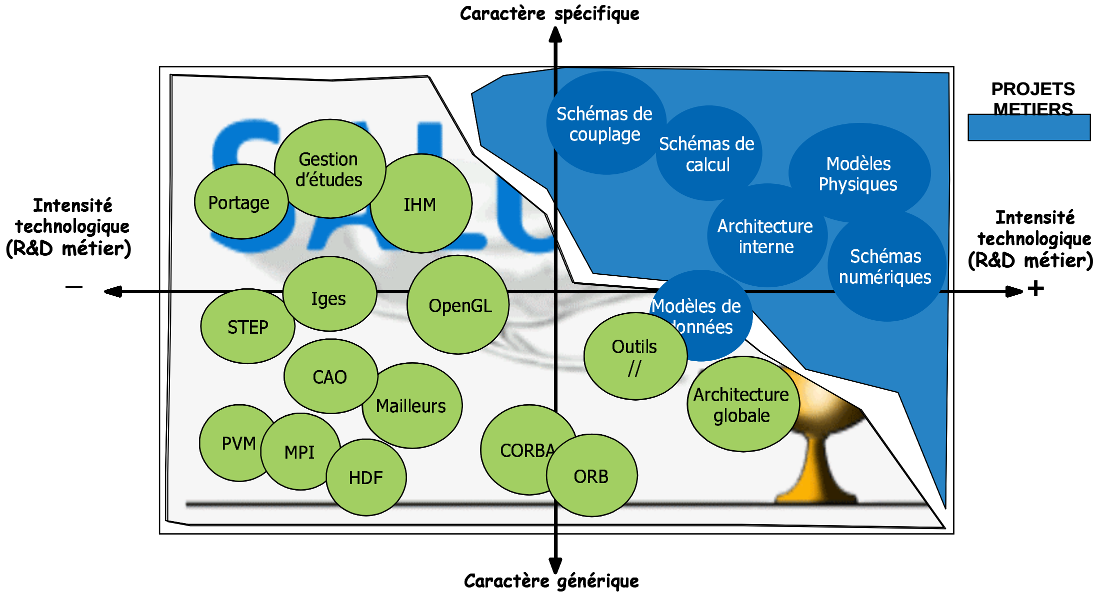


NEW IT DEVELOPMENT PROCESS

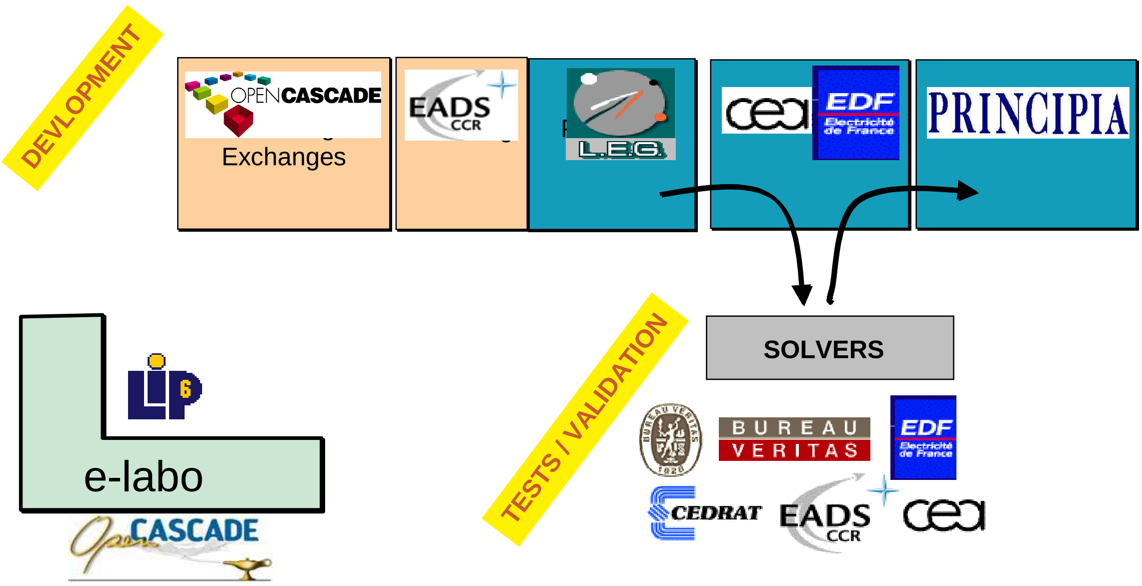


PARTNERS MOTIVATION

- To focus their R&D investment on their core competency



PARTNERS ROLE



SALOME BENEFITS

SALOME

- Improved CAD / FE integration and process
  - Geometry ready to be meshed by automatic algorithms
  - Time reduction for meshing modifications
  - Openness to any type of physics, and multi-physics
- End-user Productivity
  - Modern technology
  - Scripting language
- Independence from a software vendor's policy
  - Open Source and service approach
  - No run time fee associated with the use of the technology
  - Keep control of the development strategy

projet SALOME2

EFFORT : 23 partners

Partner	Role
OPENCASCADE	Project Management / Open Source / CAD
GOSET	Standards / STEP
cea, EADS CCR, L.E.G., CEDRAT, BUREAU VERITAS, PRINCIPIA, EDF	Numerical Simulation

CSTB, RENAULT, IFP, BRGM, ESI GROUP, ENSI, UNIVERSITE PIERRE & MARIE CURIE, UNIVERSITE de PAU et PAYS de l'ADOUR, ECOLE DES MINES DE PARIS, IRISA, 3S, LEONARD DE VINCI, ENSAM

Appendix Y: ESA Harmonisation, User Survey and Discussion Summary

ESA Harmonisation,
User Survey
and
Discussion
Summary

L. Maresi
ESTEC/IMT-THH

16th European Workshop on Thermal and ECLS S/W ESTEC 22 – 23 October 2002

ESA Harmonisation & User Survey

1. General consensus was expressed on the role of ESA for defining standards for data exchange
2. The ageing and the increasing maintenance cost are major pusher for new development
3. Tool kit is funded through ESA TRP/GSTP
4. User shall be involved, but it seems difficult to get feedback from users. Web site or internet forum may solve this problem.

16th European Workshop on Thermal and ECLS S/W ESTEC 22 – 23 October 2002

5. Tools shall improve productivity. ROI shall be taken into account when proposing new tools.
6. It is important to define upfront what “toolkit” will contain
7. Some users prefer turn-key solution. Is this possible with an OSS approach? -Yes
8. The effort required to move the users from the tools used daily to a new environment seems to be the major barrier to overcome

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9. The currents ESA funding scheme doesn't have a budget line for S/W maintenance. License fees may help to solve the problem, but an accurate cost analysis shall be made
10. Development cost shall be assessed
11. Proliferation of "upgraded"versions shall be avoided

Appendix Z: List of Participants

List of Participants

16th European Workshop on
Thermal and ECLS Software

22-23 October 2002
ESTEC, Noordwijk, Netherlands

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