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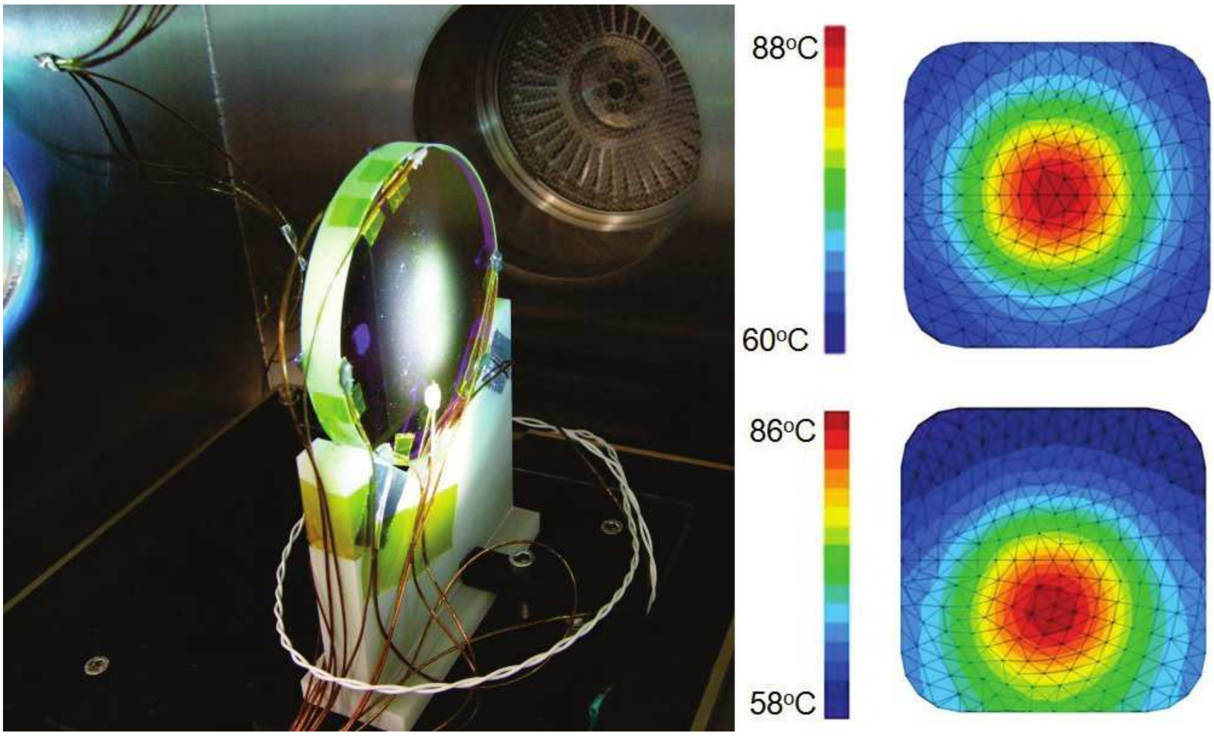

credits: RAL Space: Solar Orbiter SPICE instrument Primary Mirror thermal analysis

European Space Agency
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Abstract

This document contains the minutes of the 26th European Space Thermal Analysis Workshop held at ESA/ESTEC, Noordwijk, The Netherlands on 20–21 November 2012. It is intended to reflect all of the additional comments and questions of the participants. In this way, progress (past and future) can be monitored and the views of the user community represented. The final schedule for the Workshop can be found after the table of contents. The list of participants appears as the final appendix. The other appendices consist of copies of the viewgraphs used in each presentation and any related documents.
Proceedings of previous workshops can be found at http://www.esa.int/TEC/Thermal_control under 'Workshops'.

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Day 1

Tuesday 20th November 2012

1.1 Welcome and introduction

H. Rooijackers (ESA/ESTEC) welcomed everybody and quickly ran through the main goals of the workshop and various logistical points, such as the Workshop dinner that evening. (See appendix A)

1.2 Thermal modeling of a non-uniform solar beam in ESATAN-TMS

S. Morgan (Astrium UK) described the design of thruster units on BepiColombo to withstand the high solar flux environment around Mercury, the test configuration at the University of Bern, and the method developed to model the non-uniform beam in the solar simulator. (See appendix B)
B. Laine (ESA/ESTEC) asked how they had measured the flux in the solar simulator. S. Morgan replied that the flux had been measured by the test chamber group themselves. They had a device consisting of a 20x20 grid using measuring devices actually located in the chamber. B. Laine was interested in the details of the measurements, but S. Morgan said that the University of Bern had provided the data but he did not know how they had actually made the measurements.
J. Persson (ESA/ESTEC) noted that the figures showed a spatial distribution of flux. He wondered whether any consideration had been given to the temporal variation. S. Morgan said that they had not measured much temporal variation. There had been a small cycling over a very small amount of time. Over a two minute period they had seen a small cycle, but this had been taken into account for the steady state analysis by taking the average. They had not seen a measurable decrease in the beam during the test, so they were able to ignore any temporal variation.
B. Laine asked what temperature had been reached by the thruster units. S. Morgan said that the correlation had been successful, as expected, with the injection head, which was the critical component, staying within its temperature limits and not exceeding 75°C. Any higher and the fuel would vapourize before it reached the combustion chamber, which could lead to a so-called "vapour lock" that could stop the thruster from firing efficiently.
A. Franzoso (Carlo Gavazzi Space) asked about the order of magnitude of the thermal gradients along the different parts of the thruster. S. Morgan said that the largest gradient was from the tip of the nozzle at 250-300°C to 75°C at the bottom of the bracket. They had a 2-3°C accuracy on the thermocouples and they had had some difficulty with the correlation. The positions of the thermocouples were needed to millimetre precision. The injection head strap had spread the heat

well, so the temperature differences between the parts had been quite small.
J. Mulcahy (Astrium GmbH) asked whether the solar beam non-uniformity was important for the design of the nozzle during the mission or was it just an issue during test. S. Morgan said that it was only an issue with the test itself. They were not going to be modelling any non-uniformity in the solar mission, but in order to understand and correlate, to check that the thrusters were behaving as they expected them to, they had needed to look at this modelling technique for the test. The non-uniformity was only important during the different phases of the test where the orientation changed. They were not expecting to see any variations in solar flux during flight.
G. Jahn (Astrium GmbH) asked whether the non-uniformity of the beam was reproducible and whether this had been taken into account in the second test. S. Morgan said the beam was not reproducible, and that, indeed, the first measurement pattern they had received had been from a previous test. They had put this pattern into the model and the results just did not work, and for a long time they could not understand what was happening. In the end, they had asked the test chamber group to measure the beam again. They found that it was important to get a measurement exactly at the plane corresponding to the location of the tip of the nozzles. The previous measurement had been made a bit further forward, and because the beam was not a true parallel beam the distribution was different at different distances, and at different times it did vary. It was important to get a measurement just after the test, and in the right plane, in order to get the right distribution.
R. Briet (CNES) had noted that the results had been based on the direct solar flux, and wondered how they had prevented problems with reflections and indirect flux. S. Morgan explained that they had tried to reduce problems by creating a model of the chamber that was as close to the real chamber as possible. They had looked in the chamber to see how divergent the beam was and whether there were any unwanted reflections. R. Briet wondered whether they had needed to introduce any non-direct radiation terms to compensate for these reflections. S. Morgan said they had wrapped as much of the test sample as possible in MLI to avoid contamination from indirect radiation from other areas, and had not needed to add non-direct radiation terms in order to correlate the model. The chamber itself was very uniform, and it was quite a small chamber. They had not found any issues with variations over the chamber walls.
V. Baturkin (DLR) referred back to the slide with the grid fluxes, and wondered what had been used as the criteria for the correlation to say that they had been very good agreement. S. Morgan said that they had performed two analyses to determine the level of agreement. The first one was based on the total flux in the beam. In the second they had broken the beam down into small grid squares and had then looked at the flux in each of the small areas. He did not remember the exact details. The model gave very close agreement with the measured fluxes.
B. Laine commented that in energy terms the results appeared to agree, but the model should also take into account the 10% scattering of the flux values. Had they looked at the effect of the scattering on the distribution? S. Morgan answered that the scattering shown in the "rings" graph was due to the non-uniformity of the beam, where one ring could contain different hot and cold areas. The "grid" solution was better at taking these local variations into account. He didn't know about the level of uncertainty in the beam measurement.
J. Klement (Tesat-Spacecom GmbH) asked about the accuracy of the measurement of the flux. S. Morgan said that he would have to ask the University of Bern, because he did not know.

1.3 E-Therm New Release — Presentation of eTherm 1.2

In the absence of T. Basset (Thales Alenia Space), JP. Dudon (Thales Alenia Space) gave a brief history of the e-Therm tool, and an overview of the basic functionality. F. Brunetti (DOREA) then presented the orbitography session and the other thermal module features. (See appendix C)
V. Baturkin (DLR) asked whether e-Therm was available on Windows XP or Windows 7. F. Brunetti replied that the software had been implemented on Windows 7 but had only been fully validated on Windows XP and so he recommended that people use e-Therm on Windows XP. He expected that the effort to port e-Therm to Windows 7 would not take very long, but they would still need to replay and validate more than 200 test cases on Windows 7.
E. Friso (Universitá di Padova) commented that the TMRT module related to the thermal network, and asked whether there were any plans to develop a module for reducing the geometric or radiative part. F. Brunetti said that he would like to propose a few ideas at the NESTA meeting. One idea would be to have a consortium to promote and develop such a tool. This was one reason why JP. Dudon had been involved, because some research had already been done on this part, and DOREA would be involved in this too. Some sort of geometrical or radiative reduction would be heavily used. TAS/Cannes used analysis software in dynamic spacecraft simulation for operations and in order to have good performance it was necessary to use a reduced model. TMRT was used for the nodal reduction of the TMM, but all of the geometry reduction was still done by hand, and this took time and really needed to be automated. In e-Therm it was possible to reduce the geometry, but it was very simple based on renaming the nodes. This meant you could keep the geometry for the reduced model and just replace the nodes from the detailed model with the reduced model.
P. Zevenbergen (Dutch Space) was interested to hear more about the use of 3D conductors. He understood that this was used to calculate conductors in all directions within a solid, and wondered what would be a typical application for this function. JP. Dudon said that it could be used for all complex 3D structures with surface or volume elements, such as mirror structures for example, some parts of mechanisms, thermal conductive parts between two elements where the conduction path was difficult to perform by hand or using a high level formula. In such a case they first used a 3D finite element meshing model, and calculated the conductive path in this mesh, and then used a reduction to compute a description at the lumped parameter level, say at the instrument level.
P. Zevenbergen understood that the solid did not really exist in the thermal model, but was only really used to create conductor values. JP. Dudon confirmed that these "system level" couplings were used with the radiative couplings and the other couplings at the system level and were solved by the solver.

1.4 Advances in AblaTan Ablative Tool development with application to system model analysis

M. Giardino (Politecnico di Torino) described the development and basic functionality of AblaTan, a tool for calculating ablative shield behaviour which could then be used in ESATAN, and how AblaTan had been applied to an analysis of parts of the IXV heat shields. (See appendix D)
G. Jahn (Astrium GmbH) asked whether it had been possible to check the numerical results from the tool against actual experimental measurements of the ablative material. M. Giardino said that they had not been able to do this directly. They had some material data from their external partner,

Avio, but the vehicle had not yet flown. Once the IXV vehicle had flown, his dream was to be able to have real flight data which could be used to check the results.
G. Jahn supposed that they had some development or test data for the material itself that had been produced from wind tunnel measurements, for example. M. Giardino said that had not been possible to verify the numerical results because they had concerns about the interpretation of the material data received from Avio: there was no clear threshold for the degration, and tiles appeared to degrade at much lower temperatures than expected.
G. Jahn wondered how the chemical reactions where represented in the model. M. Giardino said that it was a simplified model which used three Arrhenius reactions in order to get better results because a test had shown that there were three main reactions in the material.

1.5 A Thermal Analysis Pre-processor

L. Bauer (Astrium Space Transportation) described and demonstrated `Promether`, a geometric model builder and thermal analysis pre-processor which was able to automatically detect contiguous surfaces and volumes in order to generate enclosures and consistent surface and volume meshing, and to calculate the appropriate conductive couplings. (See appendix E)
B. Laine (ESA/ESTEC) said that the presentation had been very impressive. He was interested to know who were the "happy users" that had been mentioned. L. Bauer said the users were the people from the thermal engineering department. He admitted that `Promether` did have a nice user interface. He felt it was important to point out that the modelling process had previously involved a lot of boring activities where the users had to work on Excel files, or edit things by hand using NotePad and so on. These boring activities were not completely over, because the scope of `Promether` today was not completely finished, it was far from being finished, but a big part of the process had now been automated where the boring and dangerous activities where it was easy to make a mistake had been replaced. There was still a lot of work to do on the load case definitions, and some cases where couplings could not be created based on the geometry, so there was still a long way to go.
S. de Palo (Thales Alenia Space) was interested to know which types of CAD format could be imported. L. Bauer said that they currently used `CATIA` to build the thermal DMU[1], which was a CAD representation that was adapted to the thermal model. This thermal DMU was then extracted from `CATIA` and imported into `Promether`. He was not completely satisfied with this solution because whenever they changed the version of `CATIA` for example, they needed to recompile the tool, which was expensive. The tool was also too tightly linked to `CATIA`. He wanted to be able to have the same solution, but going through STEP AP214 or something like that, but still with the same process. The simplification should be done in a CAD tool, because that was the core business of the CAD tool to work with geometry, and then the bridge to `Promether` would be made via STEP.
P. Zevenbergen (Dutch Space) asked whether `Promether` also provided functionality to simplify the geometry, remove holes, bolts, etc. L. Bauer believed that it was not the responsibility of `Promether` to do this: the simplification of the geometry must be done in a CAD tool. Today, in this tool chain, users had to work with `CATIA`, and he knew that this was a big constraint. He wanted to provide the same kind of process, working with any kind of CAD tool thanks to the STEP bridge, but he felt that it was important that any simplification should be done in the CAD tool. This was the core business of the CAD tool.

[1]Digital Mock-Up

P. Zevenbergen asked whether the Promether tool would be available to other parties. L. Bauer admitted that the development team was too small to be able to make significant progress with Promether as he could see that there were still years of work left to do. He was therefore interested in the possibility of collaboration with other people. In the short term it might be interesting to create a limited version of the tool which allowed simple model export so that the tool could be made available to others for evaluation.
S. Husnain (RST Aerospace) was interested to know whether surfaces had to be perfectly coplanar for the contact recognition to work. He said that sometimes there might be a small gap between surfaces, with some interface filler, and he was curious to know how the software would deal with such a case. L. Bauer said that the model needed to be as clean as possible. The default precision for contact detection was set to 10 µm, but the user could change this precision in the interface if necessary. For cases where the geometrical or contact based coupling did not work, the user would have to switch back to manual couplings and define them by hand. The idea was that the geometry based engine would cover 80-90% of the user needs.

1.6 Thermal Design and Analysis of the SPICE Primary Mirror

J. Cornaby (RAL Space) described the challenges in designing a mirror for an instrument on Solar Orbiter which needed to reflect only a small proportion of the incident solar flux with the right wavelength into the main instrument, while allowing the rest of the spectrum and energy to be transmitted through and rejected into space. (See appendix F)
J. Persson (ESA/ESTEC) commented that he had worked on the Cupola for the ISS, which also used Boron Carbide coatings, and that he remembered that there had been a lower temperature limit than the 88°C mentioned in the slides. J. Cornaby replied that they did not have a specific temperature limit in the current design, but they had not noticed any problems during testing. However, this was something that they would need to look at in the next phase of design.
S. de Palo (Thales Alenia Space) was interested in the thermoelastic analysis. The presentation had shown the need for quite a detailed model in order to have something which could be used for the thermoelastic analysis with ANSYS. He had understood that the thermal model had been built to have the same mesh as that used on the ANSYS side. J. Cornaby answered that the model had not been built to conform to the ANSYS mesh. The mechanical engineer had written a script that imported the temperatures and then related them to the mesh used within ANSYS. The thermal model did not use the same mesh as the ANSYS model. S. de Palo supposed that these dissimilar meshes were handled by running the MATLAB script mentioned. He wondered if they had thought about using the sort of pre-processors that the mechanical guys usually ran, such as PATRAN or HyperMesh, as these were able to perform some interpolation related to geometry. As far as he knew, ESATAN-TMS was also able to export geometry with coordinates, so it should be possible to have a map which would be imported into PATRAN or whatever. This could provide another way of providing temperature maps to ANSYS without having to write MATLAB scripts. J. Cornaby said that he did not know the details of the script and had left the conversion to the mechanical engineer.
P. Ferreira (Max Planck Institute) was curious about the flux table shown on the slide: how did they know that the fluxes were in these wavelength ranges? J. Cornaby admitted he did a lot of calculations in Excel: these ranges had not been calculated in ESATAN-TMS.
N. Karaismail (Turkish Aerospace) asked whether the predicted results had been compared against experimental data. J. Cornaby answered that that was what they were currently doing with the thermal testing. He had correlated the ohmic heating test with one of the models and they appeared

to be getting quite a good correlation. The big one would be the solar lamp test, which was ongoing. He hoped that they would have some nice correlations against the test data in the next couple of months.

1.7 Thermal analysis of a piezo-actuated pointing mechanism

P. Lardet (Sodern) described the development of a mounting system for the EarthCare LIDAR using pairs of piezo-actuators to give fine control over the two-axis pointing of the mirror assembly. He also described the challenges that needed to be overcome to ensure that differences in thermal gradients did not compromise the pointing requirements. (See appendix G)
V. Baturkin (DLR) asked whether there had been any problems relating to the accuracy of the calculations, the size of the mesh used, etc. P. Lardet said that there had been sensitivity studies, especially on the mesh size, and especially because of the small perturbation in the response that had been seen and which did not make physical sense. He believed that they were really at the edge of the model precision when looking at such results. He admitted that the mesh resolution was an issue. The results shown in the presentation were the results of the middle part of the sensitivity study. This study had given the direction to follow for Phase C. The mesh was clearly one of the biggest issues in the study.
V. Baturkin asked whether there had been any investigations into the results achieved using different solvers. P. Lardet said that they had not tried to use any other solvers. They had looked at heat convergence solutions, and had checked the thermal balance convergence and other things. He felt that by using a small mesh and then verifying the convergence, the solver was not an issue for this set of conductors.

1.8 SYSTEMA-THERMICA Demonstration — Part 1

M. Jolliet (Astrium) described and demonstrated some of the new developments in the `SYSTEMA` framework, including enhanced mission, trajectory and kinematic handling, geometry import from CAD, model checking using user-supplied Python scripting, video generation, etc. (See appendix H)
B. Laine (ESA/ESTEC) observed that there had been a comment towards the end about interfacing with other tools, but there had been no mention of the interface with `STEP-TAS`. M. Jolliet said that `SYSTEMA` did interface with `STEP-TAS` v6. This has not been mentioned explicitly in the presentation but he thought it had been included on one of the workflow slides.
S. de Palo (Thales Alenia Space) asked whether it was possible to model the presence of the Moon, and other effects due to both the Earth and the Moon. For example, when dealing with an orbit around the L2 position, was it possible to take into account the shadowing due to both the Moon and the Earth? M. Jolliet said that he had a case for a Lunar Lander model, developed by colleagues in Astrium Friedrichshafen. You could, of course, use the Moon: you could orbit around the Moon and use it in the trajectory, and you would be able to have the eclipse of the Moon on the satellite, but currently you could not have the Earth eclipse if you were on the Moon. The problem was that `SYSTEMA` had precision problems in the trajectory management so the smallest error in the position of the Earth, or the spacecraft relative to the Earth, resulted in a huge error for the eclipse. You may have the eclipse, but the time of the eclipse was not precise enough. They had discovered this during a power analysis case, where it had been very important to have an accurate time for the eclipse. What they had done was to allow the user to define their own

eclipses: the user could calculate the real eclipses of the Earth on the Moon and then inject them into the tool in order to have the eclipses that were needed. SYSTEMA was currently unable to calculate these eclipses with sufficient precision to offer this as a built-in feature.
A. Franzoso (Carlo Gavazzi Space) had seen that a complex geometry of an antenna had been imported from a CAD file into SYSTEMA, and wondered what happened to the mesh: was there a single node for every facet? Could the user manage the mesh in a simpler way? M. Jolliet said that when importing CAD models, there were two solutions. The first was to import the CAD model integrally into SYSTEMA shapes, and recreate the antenna for instance using SYSTEMA analytical shapes such as triangles, quadrangles, etc. but this could take some time. The second was to use the CAD model directly for the computation. In this case there would be one node per face on the CAD shape. It was not possible to submesh the CAD model because the SYSTEMA mesher was not able to cope with non-analytical shapes, such as the b-splines and other complex shapes defined in CATIA. It was possible to condense the different nodes in the model if the faces were too small and you didn't need such a fine mesh on the model. A. Franzoso asked whether the antenna had been imported as one node. M. Jolliet said that in CATIA it was possible to have a volume node defined by multiple faces but in SYSTEMA there was one node per face. He went to the SYSTEMA session to show that the antenna consisted of several meshed areas, each consisting of many individual facets, where each meshed area corresponded to a single node. He showed that in the CATIA model it was possible to have many faces per node, so for example, the five meshes on the antenna could be mapped to 5 nodes. He said this could be useful if really high precision was needed for irregular shaped meshes, the user could use the meshes directly, or could reduce the number of nodes in the mesh before importing.

1.9 SYSTEMA-THERMICA Demonstration — Part 2

T. Soriano (EADS Astrium) expanded on the previous presentation to describe and demonstrate new developments in THERMICA, including performance enhancement due to multi-threading and optimisation, ray tracing display, thermal mathematical model management and skeleton file generation, and post-processing. (See appendix I)
F. Bodendieck (OHB) was concerned about the introduction of the new $EDGES block, and asked whether there was a converter to convert the THERMISOL NWK file into a true ESATAN file for running under ESATAN. T. Soriano said that the user could select the output format from the conductive module. The options were to not create edges at all, to create them as classical thermal nodes, or to create them as edges. THERMICA offered these options because even if the edges were output as classical nodes, the temperature solver could not tell the difference between an edge and a classical node defined by the user. If the user wanted to know the flux going through shape 100 and 200, even though the flux went through an edge, if the user did not know the number of that edge and the couplings involved in that flux, the user would have to really search for this information. The fact that the solver had knowledge of the edges and the connections between the edges and the shapes, meant that when the user asked for the flux between shape 100 and shape 200, the solver would automatically compute that even though there were edges involved in the middle.
J. Mulcahy (Astrium GmbH) asked whether there were any plans to introduce 3D automatic conductance generation, as shown in other presentations. T. Soriano said that they were currently working on 3D conductor generation.

1.10 ESATAN Thermal Modelling Suite — Product Developments

H. Brouquet (ITP Engines UK) reminded everyone of the vision behind the consolidated tool suite, and how the recent releases had built on this vision to provide the performance, scalability and geometry modelling improvements needed for CAD model import and to address specific user requirements. He described the new features which would be available in ESATAN-TMS r5 to be released the following week, including an updated CADbench, improved conductor generation and pre- and post-processing, and support for planet surface modelling. He also gave details of the r6 release planned for the following summer, which would include solid modelling capabilities requested by Astrium Launchers. (See appendix J)
C. Theroude (Astrium Satellites) asked whether there would be a STEP-TAS interface for the solids which would be introduced in r6. H. Brouquet said that he would need to check with ESA to see whether solids were also supported in STEP-TAS v6.
Further questions were deferred until after the following presentation.

1.11 ESATAN Thermal Modelling Suite — Thermal Modelling Process

Y. Melameka (ITP Engines UK) gave a live demonstration of the end-to-end modelling process, concentrating on the import and simplification of a CAD model via CADbench, and showing the typical reworking required to obtain a suitable thermal model, including new ways to generate simple primitive shells to replace areas of triangular facets left over from the CAD. (See appendix K)
J. Mulcahy (Astrium GmbH) asked whether future versions of ESATAN-TMS would support multiple selection via the GUI. H. Brouquet (ITP Engines UK) said that there were plans for multiple selection. J. Mulcahy asked whether there would be support for undo and redo. H. Brouquet said undo and redo would not be available in r6.

1.12 Thermal Concept Design Tool — Future developments and TCS Projects

M. Gorlani (Blue Engineering) announced that TCDT had been ported to run on Windows 7 and Excel2010, and that this version would be available by the end of the year. He then described some of the new features that would be available in the first quarter of the following year as part of release 1.6.0, including the ability to chain orbital arcs, and improved flux calculations to take account of shadowing effects. He then presented the use of TCDT to generate and validate a simplified model of the EXOMARS EDM for coupling to the Proton Launcher. (See appendix L)
F. Bodendieck (OHB) asked whether the Proton geometry export class would be available as part of the release, or whether it had been developed specifically for Thales-Alenia. M. Gorlani said that it was an internal development created by Blue engineering, which had been needed in order to perform the activity for Alenia. The TCDT supported the use of "add-in" modules, which meant that there was a sort of open door into which users could plug in their own functionality. The class was just a plug-in to the TCDT.
B. Laine (ESA/ESTEC) said that ESA had also been involved in a similar effort to convert models for a Proton coupled launch analysis, this time for TAS France. The first time was for Sentinel, and the second for the TAS-F part of Exomars. ESA therefore also had a converter from ESATAN-TMS

to a Proton-like CSV format that could be imported into Excel, and were planning on adding this to `TASverter`. This would help other people avoid rework.

1.13 Workshop Feedback

In the few minutes before the social gathering at the end of the day, B. Laine (ESA/ESTEC) was interested to get some feedback from the participants about the workshop. He was very happy to see so many people, despite the current economic situation. He wanted to thank everyone for coming.

He wanted to have a quick show-of-hands survey about the participants to see how many people were here for the first, second, third, fifth, tenth and fifteenth times. A lot of people were attending for the first or second time, but it was clear that many people attended on a regular basis.

He said that from the following year, all ESA conferences had to demonstrate "financial equilibrium". The thermal workshop had always been free, and although it did not cost much, it was always a fight to keep the costs down. He wondered whether charging a small fee for future workshops would be an issue for any of the participants. S. Price (Astrium UK) said the workshop had always been free and relatively easy to get to, so it was easy to bring new engineers to present work. B. Laine said that it was clear that "free" meant that it was easier to get permission, and "not free" often involved a lot of administrative paperwork and approval. He hoped to be able to keep the workshop free, or low cost, or maybe even look for a sponsor.

B. Laine reminded everyone that the workshop had changed name. What should have been the 26th edition of the Thermal and ECLS workshop had become the European Space Thermal Analysis, or ESTA, Workshop. The new name brought it a bit closer to the related Network of Experts in Space Thermal Analysis, or NESTA. ESA usually took the opportunity of the workshop to schedule a meeting of NESTA.

B. Laine said that presentations on ECLS activities were still welcome, but the new name reflected an internal reorganisation within ESA and a lack of presentations on ECLS in recent years. It had been unclear whether to also add "Verification" to the title of the workshop, and whether to consider "Testing" or "Hardware" in the scope of the workshop. He wondered whether the workshop could become a more general European Thermal Workshop. He said that the presentations were high quality, and were certainly at a level that would be welcome at ICES. He stressed that this was the participants' workshop, and that everyone shaped it together based on the presentations that everyone provided.

B. Laine reminded everyone that, at the previous workshop, he had mentioned an activity to draft some guidelines on modelling and analysis. J. Etchells (ESA/ESTEC) and B. Bonnafous (ESA/ESTEC) had now produced a draft of the guidelines which was close to being ready, and which would be distributed to NESTA. He said that some printed copies would be made available the next day so that people could read them on the flight home. He would welcome any feedback and at any time: he did not want people to wait until next year's workshop! The idea was that these guidelines would form the basis for an ECSS handbook. The ECSS committee would be meeting soon to decide on next year's activities. These guidelines formed one proposal. He said it was important for people to push their ECSS representatives to get the guidelines included in the planning.

B. Laine had one final word: The social gathering was open, so enjoy the drink!

Day 2

Wednesday 21st November 2012

2.1 Innovative Analysis Methods for Improved Thermal Testing

M. Doolaeghe (Astrium) described the framework technology for linking DynaWorks with other tools to provide improved interaction, post-processing and correlation results during thermal testing. (See appendix M)
J. Persson (ESA/ESTEC) noted that only temperature extrapolation would be used during the AlphaSat test[1] and that temporal extrapolation would be excluded. He felt that temporal extrapolation would have been useful. M. Doolaeghe agreed, but said that it had probably been excluded because that functionality was not yet fully mature. A. Capitaine (Astrium) confirmed that they had decided not to use it on AlphaSat.
G. Sieber (Jena-Optronik) commented that the first correlation usually depended on the knowledge of the model in setting up the initial parameters. He wondered whether it had been easy to get all of this information from the thermal engineers before setting up the system for test. He also wondered whether the fit attained had been towards the extremes of the expected range. He had found that coupled units sometimes caused problems during fitting and wondered how well they were handled by the tool. M. Doolaeghe said that they had obtained information from the thermal engineers before the test. She admitted that the tool tended to show one high and one low value and there was currently no way to control that. The expected physical variation was given as a range, as obtained from the thermal engineers, and the tool was supposed to optimize within the range.

2.2 How SYSTEMA could provide valuable assistance in mission analysis and thermal worst cases determination

N. Liquière (Epsilon) described the 3POD moving antenna system, which was articulated to give a range of azimuth and elevation angles and which was intended to provide longer connection times with individual ground stations. He explained how SYSTEMA had been used to discover worst cases for different configurations during different operational phases around the orbit. (See appendix N)
V. Baturkin (DLR) noted that the presentation had shown a heat flux summary, but said that because the antenna was a large object, the flux density might be more important in order to avoid small points becoming overloaded. He wondered whether there was a need to orient the antenna

[1] The AlphaSat thermal vacuum test would occur some time after the workshop.

based on temperature rather than flux considerations. N. Liquière said the antenna structure was made of aluminium and was therefore very conductive, and the engineers had not felt it would be a problem to define parameters based on flux values. V. Baturkin commented that due to consideration of the quality of the materials used in the design it was often necessary to understand the exact criteria used for the optimisation.
S. Price (Astrium UK) asked about the mass of the antenna unit. N. Liquière admitted that he didn't remember exactly but could find out. S. Price asked about the parametric cases. N. Liquière answered that they had only been interested in optimising based on the fluxes, and so they had selected the parameters based on geometry.
M. Gorlani (Blue Engineering) wanted to know more about the worst case determination. The presentation suggested that there had been a complete search across all values and that the worst case had been found by looking at the results manually. He wondered whether there had been any optimisation of the search. N. Liquière confirmed that there was no optimisation at the moment and that determining the worst cases relied on engineering experience. If there were any doubts, it was always possible to scan over all of the seasons to identify other potential cases. He said that the examples shown were the well-known cases. M. Gorlani summarised that the end was reached when the scan had been made of all of the parameters and that there was no optimisation. N. Liquière agreed that this was the case.

2.3 Rationalisation of Stabilisation Criteria for Thermal Balance Tests

E. Colizzi (ESA/ESTEC) presented details of a theoretical approach that could be used to calculate a thermal time constant for any thermal network model and that this could therefore be used to determine whether a thermal test had reached stabilisation within given error bounds. (See appendix O)
A. Capitaine (Astrium) asked whether it had been possible to test the theory on a full set of measurements during a real test. He was concerned that there would be difficulties due to local time constants for different equipment. Sometimes the higher time constants were due to components with high thermal inertia, such as tanks. and then the heat transfer coefficients would converge differently. E. Colizzi admitted that he had not had a chance to undertake a full verification during a test, but had been able to make an embryonic test of the method on SWARM and had found that the theory worked.
A. Capitaine said that with the experience of IAMITT they had seen that when the test was far from stabilisation they had needed to keep two exponential terms in order to have a good approximation of the final exponential. E. Colizzi said that if they had needed to track two exponentials then the numerical method suggested that the corresponding eigenvalues would decay to a single value representing the contribution of the two exponentials.
G. Sieber (Jena-Optronik) asked whether there was any intention to put this numerical method into practice on a real test. E. Colizzi said that he hoped to do so, but there was a question of finding resources. G. Sieber asked whether there was any way of predicting how the calculated pseudo time constant would behave compared to what was seen in a test. E. Colizzi said that the numerical method was intended to help with the rational use of time during a test, and that therefore he did not feel that the question was legitimate. The duration of the test was not related to the time constant, but depended on how far you started from the conditions required for the steady state of the equation. In marginal cases the difference between the pseudo time constant and the measured behaviour could give an indication of the truncation errors and confidence in the

level of stabilisation. However, how close the starting point was from the equation depended on the test setup, on how clean the transition between test phases was, etc.
G. Sieber said it would be interesting to see how long engineers and management felt a test needed to be compared to the pseudo time constant. E. Colizzi felt that it was possible to show that the time taken for a test was related to the experience of the engineers in charge. In general the stabilisation phase was usually considered to take between three and five time constants.
B. Laine (ESA/ESTEC) said that ESA had looked at verifying the mathematics involved and it all seemed to be correct. Now it was a case of checking it against real models under test. J. Etchells (ESA/ESTEC) was currently busy with the AlphaSat testing and was hoping to apply the method to the data obtained. One problem was the noise on the measurement: it was necessary to obtain a clean curve out of the measurement in order to apply the technique. He hoped to have something to present at a future workshop. E. Colizzi noted that the paper that he had presented at ICES described the effect of noise on the parameters calculated.
J. Candé (ESA/ESTEC) observed that thermal balance testing was a very boring process. He had tried, during tests many years ago, to derive data from `DynaWorks`, and then use a spline function to identify stabilisation criteria. He had tried to make a complicated derivation to calculate the stabilisation criteria instead of relying on temperatures, but had never been satisfied with the result. He felt that it was nice to be able to play with computers to see whether there were meaningful relationships between all sorts of parameters, but in the end it all came down to temperatures measured during the test. P. Poinas (ESA/ESTEC) said that he had been involved in some of the same tests, and most of the time, when you, as the thermal engineer, thought that you had reached steady state, industry had already decided to jump to the next test phase, based on the results.
E. Colizzi felt that the test criteria needed to show stabilisation rather than just reaching a temperature value. There were various numerical criteria that could be used to determine stabilisation, such as the time constant, etc. P. Poinas argued that the time constant was always changing as the test progressed, so there was a need to decide on the convergence of the time constant as well. E. Colizzi stated that the differentiation method gave a series of curves and it should be easy to see whether there were any false indicators.

2.4 Solar Simulator Testing and Correlation of PHI Heat Rejecting Entrance Window (HREW) of Solar Orbiter

E. Friso (Universitá di Padova) presented the design of the heat rejecting window which used four coatings with wavelength dependent optical properties, how they had been modelled, and the experimental configuration required to test the model. (See appendix P)
P. Ferreira (Max Planck Institute) had noticed that the test description did not include any measurement of the distribution of the flux in the solar simulator, or how the flux decayed with radius. He wondered whether this had not been required for the test. E. Friso answered that it had been necessary for the test. They had used a Gardon sensor on the Cartesian x,y frame in order to determine the uniformity over the beam radius. P. Ferreira commented that the presentation had contained a graph of flux against wavelength, and asked whether this had been measured at one point or across the whole beam, and therefore whether the irradiance had been measured at just one point, or at several. E. Friso repeated that they had used a Gardon sensor on a Cartesian x,y frame in order to measure at many points and calculate the flux distribution of the beam.
P. Ferreira was curious to know why the temperatures had gone up as shown on slide 17 plotting temperatures against time. E. Friso said that the temperatures appeared to go up because of the scale used for the graph. The graph showed more than one hour of measurement, but only the

last fifteen minutes of measurement were used as the boundary condition. In fact, the stability criterion of 3°C per hour had already been achieved, and then the measurement continued for one hour under stable conditions, and then the mean of the final fifteen minutes was used as the value for the boundary condition.

2.5 Application of CADBench and ESATAN-TMS to the Advanced Closed Loop System

J. Mulcahy (Astrium GmbH) described the Advanced Close Loop System rack for the Columbus Module, and the process of using `CADbench` to simplify CAD models for import into `ESATAN-TMS`. (See appendix Q)
P. Zevenbergen (Dutch Space) asked at what phase of the project it had been decided to use CAD files for the geometry, and how the simplification process handled changes in the CAD files. J. Mulcahy said that they were currently working in a staggered PDR phase, so designs of some of the drawers in the rack had been finalized and some had not. They had started with the finalized models, and they expected to have minor changes in the future relating to the location of some of the components. As far as handling changes was concerned, they were typically using the same sorts of components in different places, so it was not a huge deal if these were modified, but simply a case of changing one and then copy/paste operations to handle the other locations. He said that changes to the cold plate design would be more difficult as such changes would involve much more rework.
P. Zevenbergen wondered whether the dressing down of the CAD model to remove holes, etc. could not be automated. J. Mulcahy answered that the process was not automated, the thermal engineer had to simplify the CAD import manually.
S. de Palo (Thales Alenia Space) wondered how the process handled `FHTS` models: the racks in Columbus all had cold plates which were attached to the Columbus fluid loops. J. Mulcahy admitted that they did not handle the fluid loops because some subcontractors would be looking at that part. The remit for the `CADbench` simplification work was to connect components to specific cold plates in order to create local thermal models with no obvious hot spots. These models would then be passed on to other people to connect them into the fluid loop models.
G. Sieber (Jena-Optronik) wondered whether it was possible to record `CADbench` operations in order to replay them on new CAD files. J. Mulcahy admitted that this sounded like a good idea, but didn't know how it would be possible to automate the simplification process. As each conversion was difficult, and different, he wondered how you could really automate it. Maybe it would be possible to simplify the removal of rounds and holes, but he did not know how.

2.6 Mercury Planetary Orbiter Solar Array Thermal and Power Modelling

M. Altenburg (Astrium GmbH) presented an outline of the complete BepiColombo spacecraft and its complex trajectory to reach Mercury. He described an analysis work-flow that took a detailed model of the Mercury Planetary Orbiter, created a reduced model which was used for calculating fluxes and GRs for the solar arrays, and which were then plugged into a simplified model using tables of data to calculate solar array power profiles. (See appendix R)
P. Zevenbergen (Dutch Space) wanted to know whether he had understood correctly that the Python script called the solver directly, or did the method generate tables from the solver which

were then processed by the Python script? M. Altenburg clarified that the Python script called the solver. It opened the GMM in batch mode in order to calculate the fluxes, and then ran the TMM in batch, and then extracted the results for further processing.

2.7 Dynamic Thermal Spacecraft Simulator based on nodal mathematical model

In the absence of A. Mollier (Thales Alenia Space), D. Valentini (Thales Alenia Space) briefly described the background to the activity, and then F. Brunetti (DOREA) presented how various existing tools had been brought together to create a new dynamic spacecraft simulator.
(See appendix S)
There were no questions.

2.8 Workshop Close

B. Laine (ESA/ESTEC) apologised for not introducing himself earlier as the head of the Analysis and Verification section that organised the workshop. He thanked everyone for coming, and said that it was a pleasure to see so many participants and especially presenters. He was happy to see that the tools were evolving quickly, that there was an improvement in performance, and that users were actually making use of the new functionalities. He wondered about having an on-line survey to find out what people really used and what new features they wanted. He emphasized that users should feel free to contact ESA at any time during the year, and not just wait for next year's workshop.
B. Laine reminded everyone about the Thermal Modelling Guidelines, there were still paper copies if people wanted to read on the plane, and that he hoped to have comments from industry which could be reviewed and incorporated in a reissue at the end of the year. He added a disclaimer that part of the document had been taken from an old copy of the ECSS standards from 2000 which had since been removed from the new ECSS as being informative rather than normative. The section marked with a green line was from the old ECSS. He hoped that the Guidelines would be accepted by ECSS next year so it was important for people to talk to their ECSS representatives.
B. Laine reminded everyone that they should still register for the Workshop if they had not already done so as it showed the level of interest and the value of the Workshop, and ensured people would receive links to the proceedings and the invitation to the next workshop.
H. Rooijackers (ESA/ESTEC) thanked everyone for coming, and the presenters for presenting, and brought the main part of the workshop to a close. He reminded people that there were still places available for the `TCDT` training course in the afternoon.

Appendix A

Welcome and introduction

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Appendix B

Thermal modeling of a non-uniform solar beam in ESATAN-TMS

Scott Morgan
(EADS Astrium, United Kingdom)

Abstract

Due to the non-uniformities present in some test facility solar beams, a method has been developed to account for the variations in intensity experienced across a test object. This presentation discusses a few different methods that have been used to model this within ESATAN-TMS using the inbuilt transmissivity function, and the results obtained from the analysis.

Appendix C

Presentation of eTherm 1.2

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

François Brunetti
(Dorea, France)

Abstract

In Thales Alenia Space - Cannes, we have a long experience and expertise, in the thermal software development. Concerning this point, we work with external companies like DOREA. The subject concerns the presentation, the demonstration of a new thermal software in TAS Cannes (= e-Therm). This tool is funded entirely by Thales Alenia Space - Cannes and it should not have to be commercialised but freely distributed.
This presentation is an overview of e-Therm. Today this release includes pre-processing tools (CIGAL2 for the building of geometrical models - radiative and 2D-3D conductive ...). It includes also post-processing tools like CIGAL2 for plotting graphs or cartographies.
Then, we will to talk about industrialization strategy especially based on using of our thermal software and on the integration of expert tools (2D-3D conductive module, Radiative module, Orbitography module, Solver module, Thermal model reduction tool, PTA is a tool dedicated for preliminary phases and very well adapted to the telecom program because it reuses automatically the recurrent part of spacecraft in the building of the model, friendly pre pro for telecom applications , CORAFILE , modelling / meshing) in order to improve and standardize the analysis process, in order to gain in cost and quality, for better also input/output traceability. In the soon future, we are going to integrate all the pre and post-processing modules developed initially for CORATHERM. These modules have been used on following programs : Apstar, Yamal, W6A, O3B, Irridium ...
In parallel of industrialization strategy, we develop a strategy of openness of e-Therm by distributing software free of charge to TAS-Toulouse for antenna applications and TAS-Turin for infrastructures and instruments and more generally to TAS-Group and a lot of companies.
Finally, e-Therm is well interfaced with the market tools thanks to STEP-TAS : it is an exchange standard developed by ESA more or less ready for exchanging geometrical models but not ready for exchanging thermal model. It is why a direct interface has been developed between our solver and ESATAN using TMRT without no reduction process.
Moreover, it is possibly used e-Therm for concurrent design facilities, for thermal simulator for operation and customers, and planned to extend e-Therm to other fields in physics : using in the electronic board calculation, using for simulating ESD on geostationary satellite, based on plasma / satellite interaction modelling ...

Appendix D

Advances in AblaTan Ablative Tool development with application to system model analysis

Marco Giardino Elena Campagnoli
(Politecnico di Torino, Italy)

Lorenzo Andrioli Massimo Bertone
(Thales Alenia Space, Italy)

Gianni Pippia
(SSE, Italy)

Abstract

AblaTan is the ablative shield analysis tool, developed by ThalesAlenia Space — Italy and Politecnico di Torino, fully compatible with the ESATAN-TMS suite. The tool is currently undergoing first real application on system level analysis to assess the expected advantages of integrated approach analysis versus segregated/iterative method, for which ablative tool and system model TMM are run in a standalone fashion.
First results and discussion are presented together with the tool current development status.

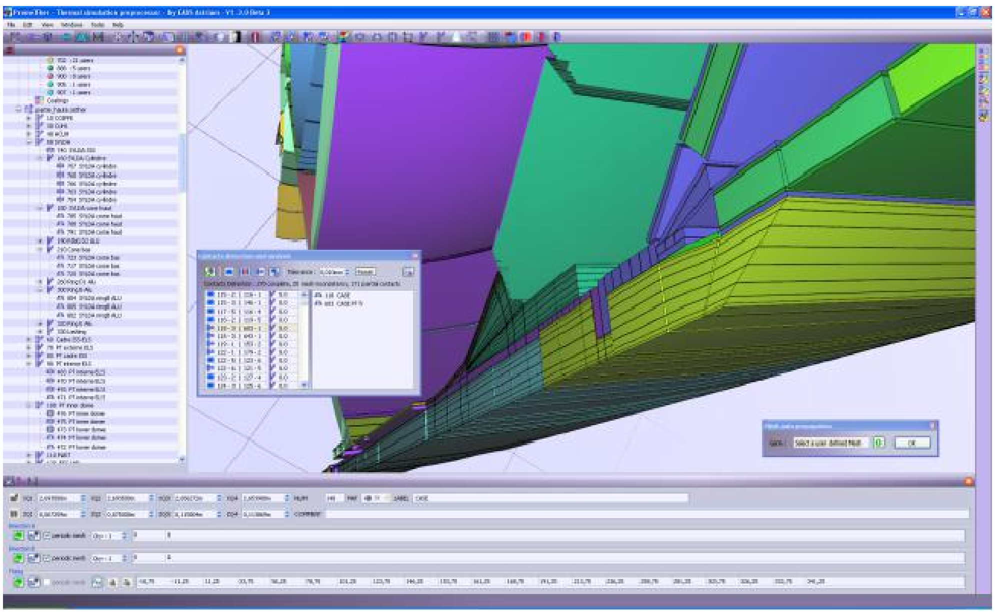
Appendix E

A Thermal Analysis Pre-processor

Laurent Bauer
(Astrium Space Transportation, France)

Abstract

Promether is a thermal analysis pre-processor.
Its basic function is to create, from a 3D solid representation, the thermal models (conductive and radiative) that will be sent to the thermal solvers.
Promether has an internal contact recognition engine that allows an automated creation of the conductive couplings. The engine also supports extraction of surface models (cavities) to prepare the radiative model. By using Promether, both conductive and radiative models derive from a same and unique reference, ensuring consistency. The nodal model can be written in different file formats, enabling compatibility with different solvers.
Promether is a white-box software, thermal analysts oriented: the 3D graphical user interface continuously helps engineers to "see inside" their models. Using 3D metaphors to represent information (material, coatings ...), the visual feedbacks helps the users and increase models confidence and reliability. Numerous quality checks are also continuously performed in background.



Appendix F

Thermal Design and Analysis of the SPICE Primary Mirror

James Cornaby
(Rutherford Appleton Laboratory, United Kingdom)

Abstract

The Spectral Imaging of the Coronal Environment (SPICE) is a payload on-board ESA's Solar Orbiter satellite. The instrument is a high resolution imaging spectrometer operating at ultraviolet wavelengths. The Rutherford Appleton Laboratory is responsible for the design and build of this instrument. Current design status for SPICE represents that at preliminary design review (PDR).

The primary mirror is a component on-board SPICE that is used to reflect EUV light to the detector assembly via a diffraction grating. The mirror is constructed from fused silica and has a boron carbide coating on the sun facing side. One of the key challenges of the SPICE instrument is for the primary mirror to manage the high heat load and resulting thermal deformations at perihelion (0.284AU). For this reason, the primary mirror has been designed to maximise the amount of EUV light (used for science observations) that is reflected whilst trying to minimise absorption in the remaining part of the spectrum. A detailed geometrical mathematical model (GMM) and thermal mathematical model has been created for this component using ESATAN-TMS. The GMM has utilised a CAD converter to ensure an accurate representation of the geometry of the mirror. The TMM has employed equations to model the spectral absorption through the silica medium of the mirror. The model is being used to provide inputs to the thermo-elastic deformation analysis of the mirror.

Appendix G

Thermal analysis of a piezo-actuated pointing mechanism

Paul Lardet
(Sodern, France)

Abstract

For the pointing of the Earthcare satellite lidar, Sodern designed a piezo-actuator tip-tilt mechanism. Each four piezo-actuator of this mechanism are equipped with two strain gages mounted in a Wheatstone bridge to precisely regulate pointing.
The behaviour of this regulation strongly depends on the thermal state of the actuators: temperature differences between actuators or gages lead to angular deviation of the mirror, and must be controlled. In particular, thermal studies were realised on two life stages of the mechanism.
During electronic system start-up, the thermal variation leads to temporary gradients delaying the availability of mirror pointing, and therefore must be minimized. Studies showed that the main factor influencing these gradients is the conduction in the system structure. The difficulty of this identification consisted in separating the influences of various parts, as the mechanism is very intricate and the required precision very fine (5mK gradients).
During operating mode, thermal variations at base plate induce gradients between the actuators. The time response of the system has been indentified in order to evaluate the spectral range of variation that must be taken into account. After that, the coefficient of influence of the base-plate temperature on the pointing performances has been determined. For that purpose, a new approach using a comparison between step response and frequency response has been developed, in order to consider small amplitude spectral thermal solicitations.

Appendix H

SYSTEMA-THERMICA Demonstration
Part 1

Maxime Jolliet Timothée Soriano
(Astrium, France)

Abstract

The SYSTEMA v4 project started in the mid 2000's and has successfully achieved its first goal: propose a new multi-physics software suite beyond on the v3 capabilities, in which new developments and evolutions becomes possible. Since the 2010's many new features and optimizations have been added and others are currently in development so to ease the process of thermal simulations from early phases to CDR, chamber test and in-orbit correlations.
Each year, the newly developed functionalities have been presented. This year's presentation is dedicated to an end-to-end use case covering the entire process from geometrical pre-processing to results post-processing, showing how the new SYSTEMA functionalities can ease thermal engineers work.
In particular, this first part covers:

- Geometry Management and Pre-processing
  - CAD geometry insertion and management
  - Import of Nastran model
  - Execution of Python script
  - Reverse orientation of multi-selection
  - Interactive geometry transformations
- Mission Settings and Management
  - Real Solar system management
  - Import of custom trajectories
  - Kinematics tree creation
  - Import of custom transformations
  - Mission's time-line and events management

Appendix I

SYSTEMA-THERMICA Demonstration
Part 2

Timothée Soriano Maxime Jolliet
(Astrium, France)

Abstract

Following the previous part of this SYSTEMA-THERMICA demonstration, this second part focuses on the simulations and results handling.
In particular, this second part covers:

- THERMICA analysis
  - Multi-threading and Ray-Tracing acceleration
  - Accuracy and modelling error handling
  - THERMICA processes and options
- THERMISOL analysis
  - Skeleton management
  - Temperature computation
  - Post-Processing toolbox
- SYSTEMA post-processing
  - 3D results mapping and video recording
  - Advanced dynamic curve, table views and csv export
  - Ray visualization

Appendix J

ESATAN Thermal Modelling Suite
Product Developments

Henri Brouquet
(ITP Engines UK Ltd, United Kingdom)

Abstract

ESATAN-TMS provides a powerful and integrated thermal modelling environment. Last year saw a major evolution of the product's analysis capability with the introduction of the functionality to perform a combined finite element / lumped parameter analysis. Developments this year have continued on improving the modelling process, focusing on reducing the overall modelling time. This presentation outlines the developments going into the new release of the product.

Appendix K

ESATAN Thermal Modelling Suite
Thermal Modelling Process

Yannick Melameka
(ITP Engines UK Ltd, United Kingdom)

Abstract

To emphasis the strength and flexibility of ESATAN-TMS a demonstration of the complete thermal modelling process shall be given. The latest version of ESATAN-TMS shall be used, with particular emphasis on the new features in the release.
See previous presentation.

Appendix L

Thermal Concept Design Tool
Future developments and TCS Projects

Andrea Tosetto Matteo Gorlani
(Blue Engineering, Italy)

Harrie Rooijackers
(ESA/ESTEC, The Netherlands)

Abstract

The TCDT is in the 6th year of distribution and maintenance. During this period the tool has evolved both according to the improvements required by the users and the enhancements included in the development plan in the frame of the maintenance contract.
The TCDT version 1.5.1, already developed and delivered to the European Thermal Community can be used on Office 2010 systems.
The new version 1.6.0 is foreseen for the first quarter of next year with some improvements:

- Flux calculation for TCDT model,
- Orbits Chains Definition

The engineers can easily use TCDT models of older versions thanks to the automatic converter provided by the 1.6.0 version.
During the 6th year of distribution some TCS projects has been developed with the use of TCDT, a short description will be provided during the presentation.

Appendix M

Innovative Analysis Methods for Improved Thermal Testing

Mélanie Doolaeghe André Capitaine
(Astrium Satellites, France)

Abstract

An R&D study by ESA, led by ASTRIUM in cooperation with INTESPACE, LKE (CZ), ETS and Global Vision Systems.

Thermal testing is part of the verification process needed on a space system. Located on the critical path of the spacecraft project, thermal testing is a complex, demanding, long and expensive task. Thermal test complexity associated to the constraints in term of cost and schedule requires efficient dedicated tools for data handling, monitoring and exploitation, in real time and after the test. Improving analyses methods and tools used to ease thermal testing is in the centre of the cost and schedule reduction problematic.
The proposed presentation deals with the activity performed in the frame of ESA R&D project Innovative Analysis Methods for Improved thermal Testing (IAMITT).
In phase one, a critical analysis of current industrial practises among all industrial space thermal companies led to identify potential improvements and select those to implement into the different modules prototyped in phase 2.
The replay of Lisa PathFinder thermal test showed the efficiency and the limitations of the different IAMITT modules:

- 3D displays gather relevant information contained in the thermal test database and dynamically link them to GMM thermal model, CAD model and pictures visualisation. The possibility of real-time visualizing all the test data available aims at increasing the spacecraft safety, facilitating the thermal team understanding, and enhancing its efficiency.
- Spatial extrapolation allows estimating the temperatures of non instrumented nodes or disabled thermal sensor in function of the temperature of instrumented ones during steady-state phase as soon as all dissipations and heater status are available.
- Temporal extrapolation predicts steady-state stabilisation, leading to a better efficiency of the test monitoring, and may lead to the shortening of test phases.
- Dynaworks database is also interfaced with a dedicated tool (TMUT) to perform model correlation by regenerating predictions with measured environment conditions but also real-time model updating using genetic algorithms.

The presentation will be concluded with some validations on a previous commercial telecommunication spacecraft but also with a short description (perhaps even the first views for this application) of the validation which is on-going on ALPHASAT in the frame of ESA R&D EVATHERM.

Appendix N

How SYSTEMA could provide valuable assistance in mission analyses and thermal worst cases determination

Nicolas Liquière
(EPSILON, France)

Abstract

Thermal design activities require a full understanding of the studied space system's mission. Standard missions are efficiently assisted thanks to the qualitative approach, especially to determine the worst external heat flow loading. For more complex missions, the qualitative approach remains vital but should be supported by a quantitative approach. This presentation is focused on demonstrate the capabilities provided by SYSTEMA v4.5 to automate the determination of the worst external heat flow loading. Based on a mobile antenna mechanism, it is shown how the mission's characteristics are handled into SYSTEMA in order to determinate parameters values leading to maximize or minimize external heat flow at the antenna subsystem level.

Appendix O

Rationalisation of Stabilisation Criteria for Thermal Balance Tests

Ettore Colizzi
(ESA/ESTEC, The Netherlands)

Abstract

When a space vehicle or its lower level elements are subjected to thermal testing, it is recurrently found that concepts such as "thermal equilibrium" and "thermal stability" are addressed lacking necessary rigor. Therefore, the quality of the results of possibly expensive Thermal Balance Tests may be diminished, if not jeopardized.
The set of concepts developed and presented are meant to allow thermal specialists to deal with stabilisation aspects of thermal balance tests on a rational ground. Moving from the theory of thermal transient analyses carried-out by means of lumped-parameter network mathematical models and using Linear Algebra, the behaviour of a network close to stabilisation is studied. The novel concepts of "instantaneous" time constant and network "terminal" time constants are introduced. The latter, in particular, is shown to be a powerful means sufficient to describe the whole network nearly-stable behaviour.
Methods to determine the terminal time constant of complex networks are illustrated, and crucial conclusions of practical interest are drawn on the ability to keep by simple means under strict control the errors arising from the truncation of stabilisation transients.

Appendix P

Solar Simulator Testing and Correlation of PHI Heat Rejecting Entrance Window (HREW) of Solar Orbiter

Enrico Friso Stefano Debei
(Università di Padova, Italy)

Giovanni Taglioni Chiara Cicciarelli
(Selex Galileo S.p.A., Italy)

Claudio Damasio
(ESA/ESTEC, The Netherlands)

Abstract

The ESA mission Solar Orbiter will provide a look at the Sun closer than ever before. Among other instruments is the Polarimetric and Helioseismic Imager (PHI) lead by the Max Planck Institute for Solar System Reseach (MPS). PHI instrument will observe the Sun through the Heat Rejecting Entrance Window (HREW) which is an optical filter that has to be placed at the entrance of the instrument acting as a filter rejecting all the radiation coming from the Sun with the exception of a very narrow spectral band around 613.3nm where it is provided a 80% transmission.

A Thermal Balance Test of HREW filter and mounting frame has been held in December 2011 using the Solar Simulator facility of CISAS University of Padova to validate the values of the thermal parameters adopted for the thermal modeling of the HREW window in operative conditions. This paper describes the solar simulator test campaign and the thermal modeling performed in order to compare numerical and experimental results. A thermal mathematical model of the test-bed with all the thermal and mechanical interfaces has been added to the filter model in order to compare the experimental data with the results of the numerical models. Thermal model correlation allow to validate the HREW filter thermal mathematical model providing more reliable prediction of thermal behavior of rejecting window during Solar Orbiter mission.

Appendix Q

Application of CADBench and ESATAN-TMS to the Advanced Closed Loop System

James Mulcahy
(EADS Astrium Bremen, Germany)

Abstract

A recent addition to the ESATAN-TMS software is the CADBench tool for transferring a variety of CAD formats directly into the esatan geometry format. This presentation assesses the initial experience of this tool applied to the Advanced Closed Loop System (ACLS). The ACLS project requires the creation of a thermal geometry with a large number of components in a short time frame and as such is considered a good test for the capabilities of the new CADBench tool. This presentation will discuss the advantages, challenges and lessons learned in the initial application of this software tool in the frame of the ACLS project.

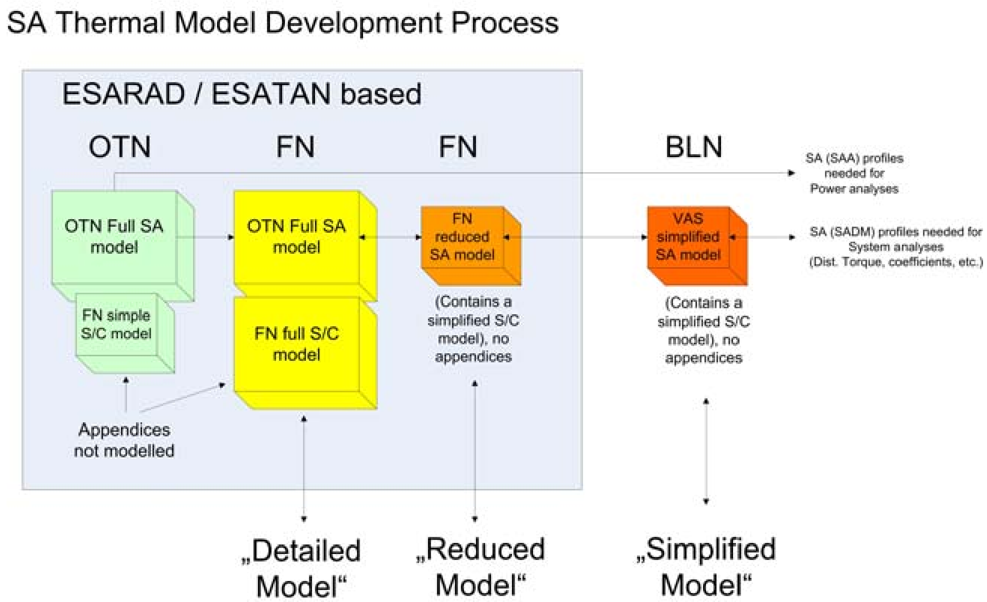
Appendix R

Mercury Planetary Orbiter Solar Array Thermal and Power Modelling

Martin Altenburg
(Astrium GmbH, Germany)

Abstract

BepiColombo is a major joint European and Japanese mission to send a planetary explorer to Mercury. As such BepiColombo is exposed to high thermal loads. One of the most critical subsystems on BepiColombo is the MPO Solar Array.
This presentation gives a short overview of the "simplified" thermal solar array model, which has been derived from the "detailed" and "reduced" model and is used to analyse thermal and power performance on the spacecraft. The "simplified" model uses the attitude and position of the spacecraft and SADM with respect to Mercury to determine the temperature of the hottest solar array cell. The "simplified" model will be used by ESA to generate solar array drive profiles in the course of mission planning.



The presentation will look into two different approaches for solving the thermal network. The first is applied by the "reduced" solar array model, with an interface script for solving temperature dependent moving geometry iterations with ESATAN TMS. The second approach is followed by the "simplified" solar array model, which uses an independent mathematical description of the thermal loads from Sun and Mercury on the Spacecraft without relying on classical thermal analysis tools. Results obtained by these two approaches are compared vice versa and with results calculated by the "detailed" model in consideration of numerical effort and accuracy of the temperature results. In addition, a short outlook for the further development of the "simplified" model and the power model will be given.

Appendix S

Dynamic Thermal Spacecraft Simulator based on nodal mathematical model

Anthony Mollier
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François Brunetti
(Dorea, France)

Abstract

To improve the quality and reliability of the dynamic spacecraft simulator, Thales Alenia Space Cannes asked DOREA to implement the thermal real-time simulator based on the thermal mathematical model (TMM) provided by thermal analysis team.

Both SYSTEMA/Thermisol (from EADS Astrium) and ETHERM (from Thales Alenia Space) nodal models have been converted and integrated into a new DSS product line called SCSIM (SpaceCraft SIMulator). A set of ESA tools were used in an industrial context to solve this technical challenge: reduction tool TMRT (without reduction) has been used to convert TMM from SYSTEMA/Thermisol nodal definition; STEP-TAS and TASverter to convert geometrical model from THERMICA and thermal post processing tool ESATAP for thermal model comparison and debugging.

Ray-tracing calculator and temperatures resolution from internal ETHERM core module (former CORATHERM) have been successfully improved to fit the real-time constraints. Parallelisation has been largely used to make the calculation most reactive in order to fit as much as possible the physics behaviour.

New SCSIM based on TMM has been successfully validated on Alphasat (@bus platform) and O3B Networks satellite.

Appendix T

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