# Appendix K

## A personal look back on Thermal Software evolution within the past 36 years

Harold Rathjen
(HRC, Germany)

**Abstract**

The evolution of thermal software used in European space industries from the beginning until today marks a long way from some in-house written software to the current status of today's most important packages. During almost 30 years this way was accompanied by the ESTEC annual workshop on ECLS software that started in 1986 as the Esatan workshop, but soon had to be opened for other software developments, among which Thermica has to be mentioned in first place. This presentation gives a historical look back from a personal point of view of a young thermal engineer who started working in the thermal department of ERNO in Bremen right at the time when the Spacelab project was won and the first family of commercial communication satellites (ECS/MARECS) was started. Some highlights are the decision for the cooperation between ESTEC and a little company in England to develop Esatan, and a few years later the search for an appropriate radiation software for the Columbus project. Not to forget the Esabase framework, that was used during many years as an intermediate software. Finally the problems of establishing a common thermal analysis method within the Ariane project in front of the merging of the participating companies are mentioned.

# A personal look back on Thermal Software evolution within the past 36 years

Harold Rathjen, recently retired from Astrium Bremen

28th European Space Thermal Analysis Workshop,
Noordwijk, Oct.14th 2014

1

## Contents



2

## 1. The days before Esatan

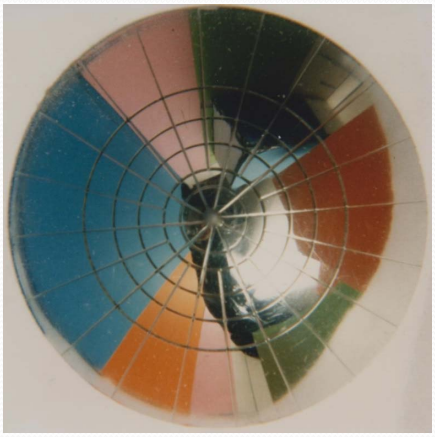
This period lasted from the first European space activities (in the early sixties) until the introduction of ESATAN in most of the European space companies. It was characterised by the following:

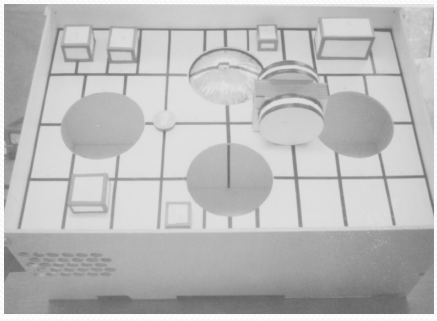
- In the early years no off-the-shelf thermal software was available and companies had to rely on their own in-house written software
- In ERNO these were GLEITEX for steady state and TRANSIT for transient analyses (developed for the Helios project)
- Models were defined in punch cards and output was given on endless computer paper, i.e. it could not be directly used for the report but had to be included via cut and paste
- Computations were performed in a remote computer center with partly tremendous costs leading to the strange situation that the engineers spent extra effort in order to save computer CPU time

3

## 1. The days before Esatan (cont'd)

- View factors were defined manually with the help of a view factor meter applied in a wooden scale model of a satellite
- A view factor meter was a small parabolic mirror with a grid on it that was placed on surface i in the model. The percentage of the grid that was covered by the mirror image of surface j gave then the view factor to that surface
- Each relevant internal radiative link had to be defined that way and the results had to be written into form sheets that were then processed by a software (SPIEGEL) considering multi reflection and outputting the relevant conductor format





4

## 1. The days before Esatan (cont'd)

Around 1977 when the Spacelab project started, the NASA Thermal Software SINDA was distributed by ESTEC to the European space industry, accompanied by further software:

- NASA radiative software called LOHARP with following 4 modules:
  - VUFAC View factor calculation using double integral method
  - RADCON Computation of multi reflection
  - ROHEAT Computation of natural radiation
  - PRTPCH Outputting the results in SINDA format
- Later ESTEC established a revised version of LOHARP and distributed it under the name VWHEAT with the same 4 modules
- For visualisation of the used geometries a simple plot program called PTD10 was also provided. It was only a wire frame display without hidden line feature but nevertheless was well appreciated
- All was provided with the source code

5

## 1. The days before Esatan (cont'd)

In the period that followed, SINDA was established at ERNO, at least for the most important projects (Spacelab and the new European family of communication satellites OTS/ECS/MARECS)

- The old programs/methods were used in parallel for a long time
- The results of the radiative software and even of the form factor meter method, once established, were used during almost the complete life time of the model. The manual introduction of modifications (e.g. for taking into account new surface properties) was deemed easier than repeating the calculations due to the high CPU times
- During this time still a lot of little Fortran programs were written by the thermal engineers to handle and modify model data and to plot transient temperature results
- In the early eighties we made a test of the thermal module of Nastran in cooperation with our structural colleagues. The result was not very encouraging (at that time!) and we soon gave up

6

## 2. The European Thermal Analyser Network and first Workshops

While industry was working with the a.m. NASA software, ESTEC was thinking about a completely new European thermal software, the driving power behind this being Mr. Charles Stroom of ESTEC/TST:

- First idea was to create a software corresponding to the state of the art combining thermal and radiative analysis in one tool
- Working title for this ambitious project was MANIP and a very first version was presented to space industry under the name of MINIP (around 1982 ?) which indeed looked very impressive but a long development time had to be envisaged
- While MANIP was internally further pursued it was then decided to proceed in small steps and to begin simply with a European version of SINDA. In fact, still today ESATAN consists of the same block structure as SINDA

7

## 2. The European Thermal Analyser Network and first Workshops (cont'd)

- It was furthermore decided to assign the development of this sofware to an external company under ESTEC contract and finally the Mechanical Engineering Laboratory (MEL) of GEC in England was selected. Today known as ITP, this company is still responsible for ESATAN

The first version of the new software was presented by Mr. John Turner of MEL on the first (ESATAN-) workshop that took place in April 1985 and that was organized by Ch. Stroom

- Representatives of 25 companies participated out of 37 that were invited. They had first contact with the software during hands-on sessions on the ESTEC IBM mainframe
- As for the software provided by ESTEC before, distinction had to be made between the various computer platforms used, not only w.r.t. the software itself, but also to the run procedure

8

## 2. The European Thermal Analyser Network and first Workshops (cont'd)

- Most companies had DEC-VAX and IBM mainframes, while PCs did not yet play a significant role

The next 3 workshops, at that time called ESATAN User Meeting, took place in 1987, 1989, and 1990

- These were characterised by user presentations about their companies experience with ESATAN and discussions about how to improve the software
- Major issues were the computation speed and stability, modelling problems and output options
- Also the flow software FHTS and its integration into ESATAN was a subject
- Different hardware platforms were still under discussion, e.g. to make ESATAN run on multi processor machines

9

## 3. The ESABASE Framework

In the early eighties another software tool was available from ESTEC, called ESABASE, this time provided by the mathematical department WMA and probably resulting from the MANIP development

- It was a framework intended as a multi disciplinary tool where a common geometry model could be used for various analyses tools such as:
- Thermal, Radiation, Plume, Mass, Atomic Oxygene, Perturbation, Meteorite/Debris, Charging, Field of View and others
- It provided a modelling environment and its own language to define the geometry. Today this language (with some modifications) is still used in THERMICA
- An orbit generator ORHPL and a graphical interface for pre and post processing were also available
- The first presentation of ESABASE at the workshop was in 1993 after the software existed already some ten years

10

## 3. The ESABASE Framework (cont'd)

- At ERNO we had installed ESABASE since the beginning with the following software attached:
  - VWHEAT with its 4 modules (see above)
  - SINDA – it was used at ERNO in parallel with ESATAN for a long time for projects with interfaces with NASA (e.g. the German SPACELAB missions D1 and D2)
  - ESATAN – included when it became operational at ERNO
  - THERMICA with its modules MATRAD and MATFLUX (see next chapter)
  - PATRAN – used for visualisation of the geometry and for post processing with coloured overlay
  - Mass – not used in thermal department
- Interfaces with Esarad and Ideas/TMG became available later
- With the exception of VWHEAT this software configuration was the main thermal modelling environment used at ERNO (meanwhile becoming DASA) until we switched to the stand-alone versions of THERMICA and ESATAN (around 1998 ?)

11

## 4. The European Radiation Software

In the late eighties the European space industry was preparing the start of the COLUMBUS project. It was clear that ESATAN would be used as thermal analyser but a corresponding radiation software was still missing

As the COLUMBUS prime contractor, it was the task of ERNO to find an appropriate tool and in fact there were two candidate solutions available:

- At DORNIER in Germany they had meanwhile spent some effort to develop a new version of VWHEAT (STARDUST) and indeed they had achieved a considerable improvement. However, view factor calculation was still based on the double integral method
- At MATRA in France, who co-operated at that time with the ESTEC mathematical department WMA for the MANIP development, they proposed a new software based on the ray tracing technique (MATRAD and MATFLUX)

12

## 4. The European Radiation Software (cont'd)

- Under the working title COLUMBUS Bridging Thermal Software (CBTS) a comparative study between the two was started at ERNO
- As a result it was found that MATRAD/MATFLUX was approximately 10 times faster and provided a lot of additional advantages
- Hence it was decided that MATRAD/MATFLUX should be used within the COLUMBUS project
- Later on these two modules and an also existing visualisation tool called MATVIEW were combined under the name THERMICA
- THERMICA soon became the most important radiation software long time before ESARAD was available and was also successful on the American market

13

## 4. The European Radiation Software (cont'd)

Nevertheless, it was the intention of the ESTEC thermal department YCV to develop their own radiation software. There was obviously an internal dissent between WMA with MATRA on one side and YCV on the other about the software development policy

- This is probably the reason why today we have two concurrent European thermal software tools: SYSTEMA-THERMICA and ESATAN-TMS
- This is good for competition but on the other side, wouldn't it be more efficient to put all development effort into only one tool?
- It was then an evident decision that GEC was assigned to develop this software under the name ESARAD
- Due to contractual reasons WMA had to provide the kernel of their tool to GEC who built ESARAD around it, which hence is also based on the ray tracing technique

14

## 4. The European Radiation Software (cont'd)

- The development of ESARAD was first announced on the 1990 workshop and the first version was presented on the next workshop in 1991
- The 1991 workshop was the only one so far that took not place in Noordwijk, but was scheduled together with the ICES conference which that year took place in Florence, Italy
- Therefore a lot of thermal people where present, among them the head of thermal department in Bremen, and I could convince him together with GEC people to allow the purchase of our first Sun/Solaris work stations that were needed to run ESARAD
- Thus we could early familiarise ourselves with the dominant hardware platform for the next couple of years
- A few month later we had our first ESARAD installation in Bremen and we became early (beta-) users of a new software

15

## 4. The European Radiation Software (cont'd)

- Different from the first ESATAN version we had, I must say that working with this early ESARAD version was really hard and it was far away from being applied for a real project
- One reason for this was the concept of ESARAD to define the model on the screen and to store everything directly in a model data base without the use of an ASCII input file
- When the software crashed for whatever reason the data base could not be restored and all work was lost. It was said that all data were stored on the session log file, but before reloading the relevant model data from there, this log file had to be cleaned, which was not so easy
- Today this problem is solved by the option to automatically create a clean log file at any time during model creation which allows the user to reload or copy the model

16

## 4. New European Radiation Software (cont'd)

- Another reason for the early problems was the ORACLE software used for the model data base. A reduced ORACLE version has been provided together with ESARAD that often was in conflict with our own Oracle installation in the ERNO network
- Meanwhile the use of ORACLE in ESARAD was given up

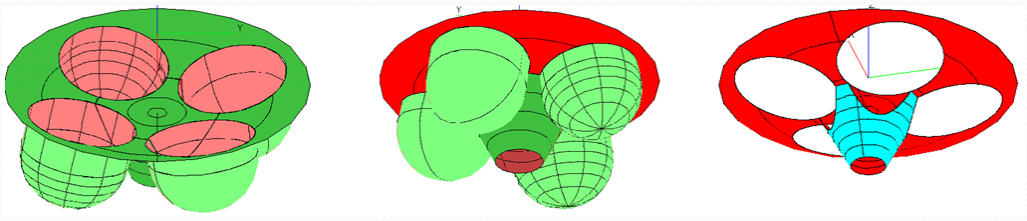
As a big advantage of ESARAD the new cutting tool was considered which allows to cut the existing set of primitive shapes to more complex shapes

- One example, reported on the 1995 workshop, was the Soho space craft space simulation test were a good correlation could only be obtained after remodelling the INTESPACE test chamber under extensive use of the cutting tool. Without cutting the cylindrical chamber walls, intruding each other and, moreover, being partly not covered by the cold shroud, could not be correctly modelled

17

## 4. The European Radiation Software (cont'd)

- The other example is my own model of the upper stage EPS of the new Ariane 5 launcher as shown below:



- The lower side of the stage consisted of a large spherical structure with cylinders and cones intruding each other
- Radiation played a significant role in that area due to the very hot engine and nozzle (not shown in the figure)
- Therefore this feature would have been very helpful for this model but unfortunately ESARAD became operational too late and I had to work around without cutting

18

## 4. The European Radiation Software (cont'd)

- The conventional method to model the above geometry was to approximate the cutting edges by small bits of non-cut primitives. However for curved shapes this was difficult and led to a unnecessary high number of nodes
- At DASA, ESARAD became operational around 1998 but still was not always robust. Only after switching from Solaris to Windows workstations ESARAD worked satisfactory

19

## 5. Integrated Thermal Analysis Tools

Today each of the two European thermal analysis packages is available as fully integrated tool for radiation and thermal analysis including pre and post processing operated from a common graphical user interface. Furthermore both provide an automatic conductor generation based on the geometry

- ESATAN/ESARAD became ESATAN-TMS recently enhanced by the solid modelling feature as commonly required by AST-LMX and AST-BRE for the Ariane project
- THERMICA was enhanced by its own thermal solver THERMISOL and became SYSTEMA-THERMICA. V4 is not yet operational in Bremen, as the step from v3 is considered too big to be done in a running project
- Some other software packages providing similar features have also been considered or are used at Dasa (later Astrium) in Bremen

20

## 5. Integrated Thermal Analysis Tools (cont'd)

- When we started the analyses of the new cryogenic upper stage for Ariane 5 ESC (ESC ) we engaged a TMG expert to sit in my office and build a TMG model of ESC in parallel to my ESATAN modelling. The result after some months was, that TMG was not a suitable alternative, namely w.r.t. the radiative part (today the result might be different!)
- For the same project also some FEM tools (a.o. SAMSEF) were considered but were all deemed not suitable
- For projects with interfaces with NASA we are using the (US-) Thermal Desktop software that is also fully integrated with AUTOCAD as GUI, SINDA and a ray tracing radiation software (NEVADA)
- An extensive thermal software development was going on in the Ariane world (Astrium, Les Mureaux) but unfortunately was not present on the workshops before 2012

21

## 6. Workshop Milestones

1985: Presentation of first ESATAN version - Followed by 3 ESATAN User Meetings in 1987, 1989 and 1990

1991: Presentation of first ESARAD version - Took place together with ICES conference in Florence, Italy – An Overview over Soviet Standard Software for thermal modelling of Spacecraft was give by Prof. Anfimov from Kaliningrad was given

1992: Increasing participation of other software, e.g. TMG, ECOSIM, and many others. Users present projects, for that the software was used

1993: First presentation of ESABASE on the workshop, workshop renamed to Workshop on Thermal and ECLS Software

1994: First presentation of STEP-TAS

2001: First presentation of THERMICA on the workshop

2012: Renamed to Space Thermal Analysis Workshop

22