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Space engineering - Thermal analysis handbook

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Raumfahrttechnik - Handbuch für thermische Analyse

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European Foreword

This document (CEN/TR 17603-31-17:2022) has been prepared by Technical Committee CEN/CLC/JTC 5 "Space", the secretariat of which is held by DIN.

It is highlighted that this technical report does not contain any requirement but only collection of data or descriptions and guidelines about how to organize and perform the work in support of EN16603-31.

This Technical report (CEN/TR 17603-31-17:2022) originates from ECSS-E-HB-31-03A.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any TR covering the same scope but with a wider domain of applicability (e.g.: aerospace).

1 Scope

1.1 Objectives and intended audience

This handbook is dedicated to the subject of thermal analysis for space applications. Thermal analysis is an important method of verification during the development of space systems. The purpose of this handbook is to provide thermal analysts with practical guidelines which support efficient and high quality thermal modelling and analysis.

Specifically, the handbook aims to improve:

- a. the general comprehension of the context, drivers and constraints for thermal analysis campaigns;
- b. the general quality of thermal models through the use of a consistent process for thermal modelling;
- c. the credibility of thermal model predictions by rigorous verification of model results and outputs;
- d. long term maintainability of thermal models via better model management, administration and documentation;
- e. the efficiency of inter-organisation collaboration by setting out best practice for model transfer and conversion.

The intended users of the document are people, working in the domain of space systems, who use thermal analysis as part of their work. These users can be in industry, in (inter)national agencies, or in academia. Moreover, the guidelines are designed to be useful to users working on products at every level of a space project – that is to say at system level, sub-system level, unit level etc.

In some cases a guideline could not be globally applicable (for example not relevant for very high temperature applications). In these cases the limitations are explicitly given in the text of the handbook.

1.2 Context

The use of computational analysis to support the development of products is standard in modern industry. Figure 1-1 illustrates the typical thermal modelling and analysis activities to be performed at each phase of the development of a space system.

NOTE More information about the project lifecycle can be found in ECSS-M-ST-10 [RD5].

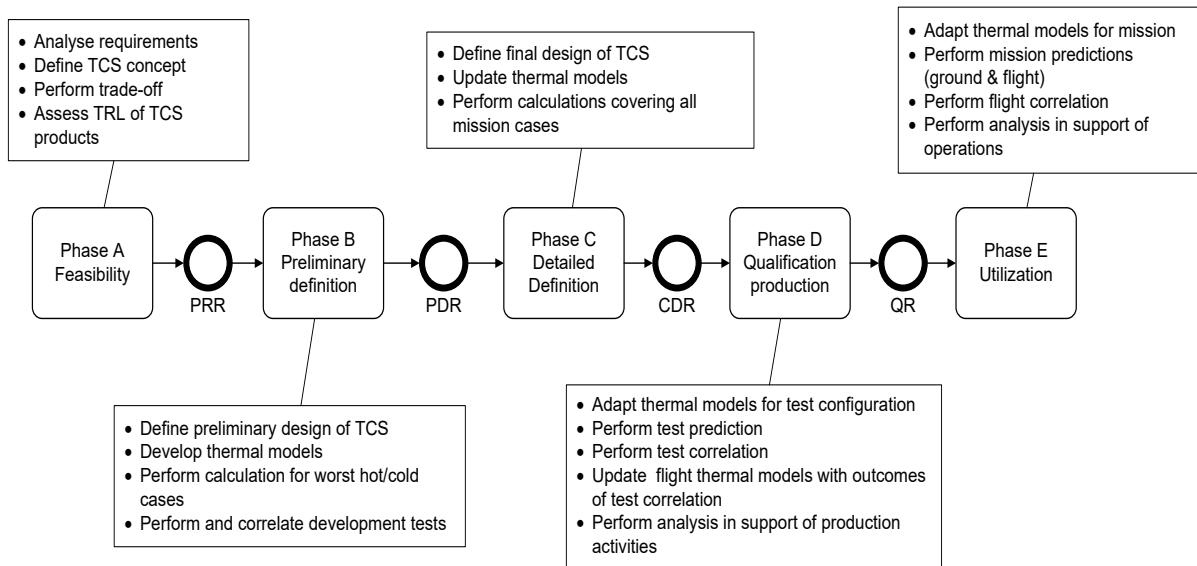
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Figure 1-1: Thermal analysis in the context of a space project

It can be seen that thermal models are used during all phases of the space system development to support a large number of activities, ranging from conceptual design right through to final in-flight predictions.

Indeed, in some cases, thermal analysis is the only way that certain thermal requirements can be verified; as physical tests are either too expensive or unrealisable. It is therefore vital for the credibility of the predictions made that the quality of the models is as high as possible.

2

References

RD #	EN Reference	Reference in text	Title
[RD1]	EN 16603-31	ECSS-E-ST-31,	Space engineering - Thermal control general requirements
[RD2]	EN 16603-32-03	ECSS-E-ST-32-03	Space engineering - Structural finite element models
[RD3]	EN 16603-31-02	ECSS-E-ST-31-02	Space engineering - Two-phase heat transport equipment
[RD4]	TR 16603-31-01	ECSS-E-HB-31-01	Space engineering - Thermal design handbook
[RD5]	EN-16601-10	ECSS-M-ST-10	Space project management - Project planning and implementation
[RD6]	EN 16601-00-01	ECSS-S-ST-00-01	ECSS system – Glossary of terms
[RD7]			Gilmore, D., G., "Spacecraft Thermal Control Handbook – Volume 1: Fundamental Technologies", 2002
[RD8]			Anderson, B. J. and Smith, R. E. "Natural Orbital Environment Guidelines for Use in Aerospace Vehicle Development", NASA Technical Memorandum 4527, June 1994
[RD9]			Anderson, B. J., Justus, C. G., and Batts, G. W. "Guidelines for the Selection of Near-Earth Thermal Environmental Parameters for Spacecraft Design", NASA Technical Memorandum 2001-211221, October 2001
[RD10]			Anderson, B. J., James, B. F., Justus, C. G., Batts "Simple Thermal Environment Model (STEM) User's Guide, NASA Technical Memorandum 2001-211222, October 2001
[RD11]			Sauer, A. "Implementation of the Equation of Time in Sun Synchronous Orbit Modelling and ESARAD Planet Temperature Mapping Error at the Poles ", 22nd European Workshop on Thermal and ECLS Software. October 2008. https://exchange.esa.int/thermal-workshop/attachments/workshop2008/

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RD #	EN Reference	Reference in text	Title
[RD12]			"Feasibility of Using a Stochastic Approach for Space Thermal Analysis", Blue Engineering & Alenia Spazio, 2004, https://exchange.esa.int/stochastic/
[RD13]			"Guide for Verification and Validation in Computational Solid Mechanics," The American Society of Mechanical Engineers, Revised Draft: 2006
[RD14]			Remaury, S., Nabarra, P., Bellouard, E., d'Escrivan, S., "In-Flight Thermal Coatings Ageing on the THERME Experiment" CNES, Proceedings of the 9th International Symposium on Materials in a Space Environment, 2003 Noordwijk, The Netherlands
[RD15]			M. Molina & C. Clemente, "Thermal Model Automatic Reduction: Algorithm and Validation Techniques", ICES 2006.
[RD16]			F. Jouffroy, D. Charvet, M. Jacquiau and A. Capitaine, "Automated Thermal Model Reduction for Telecom S/C Walls", 18th European Workshop on Thermal and ECLS Software, 6-7 October 2004
[RD17]			Gorlani M., Rossi M., "Thermal Model Reduction with Stochastic Optimization", 2007-01-3119, 37th ICES Conference, 2007, Chicago
[RD18]			M. Bernard, T. Basset, S. Leroy, F. Brunetti and J. Etchells, "TMRT, a thermal model reduction tool", 23rd European Workshop on Thermal and ECLS Software, 6-7 October 2009
[RD19]			STEP-TAS Technical Details http://www.esa.int/TEC/Thermal_control/SEME7_NNOLYE_0.html
[RD20]			CRTech, "How to Model a Heat Pipe", http://www.crttech.com/docs/papers/HowToModelHeatpipe.pdf
[RD21]			Juhasz, A., "An Analysis and Procedure for Determining Space Environmental Sink Temperatures with Selected Computational Results", NASA Technical Memorandum 2001-210063

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