Book Reviews

Spacecraft Thermal Control

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Woodhead Publishing Limited, 80 High Street, Sawston, Cambridge, CB22 3HJ, UK. 2012. 382pp. Illustrated. £160. ISBN 978-1-84569-996-3.

The authors of this book, all from the Universidad Politécnica de Madrid, have much professional experience in spacecraft thermal control, both in academic research/teaching and as contributors to numerous flight programmes. Their intended target audience is graduate students, engineers starting out in this field and system engineers requiring an understanding of the thermal subsystem. The book is organised into clear self-contained chapters, each with an abstract and keywords given at the beginning and specific references given at the end. This is very useful if the reader is researching a specific topic, as it can be readily 'dipped into' for the key ideas and the references followed if more detailed information is required. The structure of the book also makes it very readable in its entirety, with each chapter expanding on concepts introduced earlier.

The first three chapters of the book provide a general introduction to space missions and basic space systems engineering, which would allow a reader unfamiliar with space engineering to understand the role of thermal control in spacecraft. It also places the thermal control subsystem within the context of the other spacecraft subsystems and the space environment. The chapter on Keplerian orbits covers the fundamentals of orbital mechanics, including some discussion of resulting lighting conditions and eclipses.

The subsequent two chapters introduce the theoretical basis of thermal control. The thermal conduction chapter introduces Fourier's Law and the heat diffusion equation in different coordinate systems. Tables of thermal properties of commonly-used space materials provide a helpful resource. A brief introduction to numerical methods for analysing heat conduction is given; this is expanded further in a later chapter on thermal mathematical models, which gives examples of commercially-available software packages, in particular ESATAN-TMS.

The thermal radiation chapter covers the principles of thermal radiation, both from a theoretical basis and applied to real situations (thermo-optical properties of real surfaces, view factors). The following chapter then goes on to explain how thermo-optical surface properties can be used for thermal control. Examples of optical coatings are given in this chapter, with extensive tables of properties taken from a variety of quite recent sources. The effect of ageing on thermal control surfaces is also discussed, with some selected examples given.

A large part of the remainder of the book addresses specific equipment and techniques used in regulation of spacecraft onboard temperatures. Thermal insulation is presented in the context of both the key technologies used (multilayer insulation blankets and foams) and the philosophy behind their use, of decoupling the spacecraft as much as possible from the thermal environment and its variations. The concepts of effective emissivity and conductivity are introduced. There is also a useful review of work on thermal contact conductance, an area where it is often difficult to obtain baseline values for initial thermal design studies, with some examples given.

The chapter on radiators explains the techniques used to reject heat and covers both design of the radiating surfaces and methods used to transport heat to them, such as fluid loops and heat pipes (more detail on design of both of these is also given in later chapters). It

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includes a number of examples of spacecraft and instruments and the radiators designed for them. Cryogenic and thermoelectric cooling, and refrigeration systems are also discussed in some detail, again with real-world equipment examples and details of the thermal requirements for selected instruments.

The 'hardware' part of the book also includes a discussion of the applications, design and performances of louvers and phase change materials. Again, tables of material properties are provided. Spacecraft heaters and heater control is also covered, including some mention of the use of radioisotope systems. Finally, thermal protection for atmospheric entry is presented, with examples given of both radiative and ablative systems.

The final part of the book places thermal control subsystem design, analysis and test in the context of the overall space project. It gives the philosophy of the design process, showing how all the elements in the preceding chapters are considered, in order to produce a complete functioning thermal control subsystem that meets the mission requirements. Thermal testing approaches are described, with discussion of test levels and test model philosophy and the facilities required. Useful references are given to the relevant ECSS standards documents.

Overall, this is a very readable book, which does not assume much in the way of prior knowledge and provides numerous useful examples. All the key areas are covered, with a level of technical detail that is comprehensive without being overwhelming. It would be appropriate for a junior systems engineer conducting preliminary thermal analysis and thermal control subsystem design in a mission concept study, but also gives enough depth and useful references to be an appropriate resource for a more experienced thermal engineer.

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Theoretical and Computational Aerodynamics

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It is a major undertaking to write a book covering such a wide area of aerodynamics, so the author should be commended for his efforts. The book is generally well-written, with enough background and historical text to keep the reader's interest and is split into two main sections: the first comprising general theoretical background and methods for fluid mechanics and aerodynamics; the second focussed on computational studies. However, it is important to stress that, as the author states in the background text, the computational part considers 'recent applications made possible by computational aerodynamics'. Hence, the book is not aimed at presenting detailed numerics of computational methods used in aerodynamics.

The book comprises almost 500 pages, split into 13 chapters, the first seven covering theoretical aspects. It begins with three introductory chapters, covering basic fluid mechanics, derivation of Navier-Stokes equations, stream function and vorticity, potential flow solutions and introducing thin aerofoil theory. This is followed by chapters presenting finite wing theory, a brief introduction to panel methods, slender wing theory, slender body theory and a section on vortex breakdown and finally a chapter on boundary layer theory. This is all standard content, but is thorough, well-written and interesting.

The computational part starts with a chapter presenting very brief details of temporal and spatial scales and stability for a simple wave equation, then brief details of a specific high-order