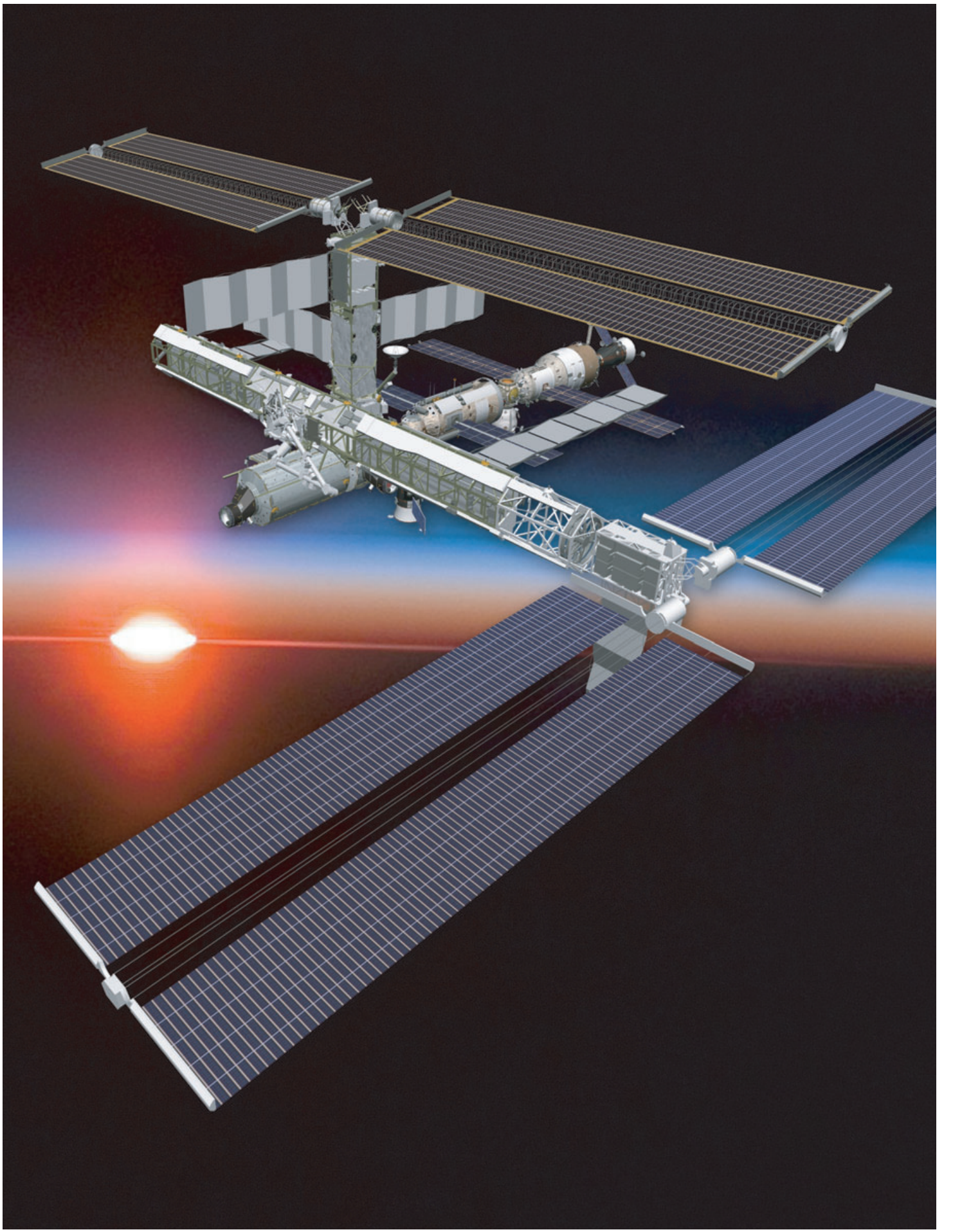
Handbook of Space Technology



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WILEY
A John Wiley and Sons, Ltd., Publication

This edition first published 2009 by John Wiley & Sons, Ltd

First published under the title Handbuch der Raumfahrttechnik 3.A.
by Carl Hanser Verlag © 2008
Editors: Wilfried Ley, Klaus Wittmann, Willi Hallmann
Carl Hanser Verlag GmbH & Co. KG, Munich/FRG, 2008.

Registered office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

Library of Congress Cataloging-in-Publication Data

Record on File

ISBN: 978-0-470-69739-9

A catalogue record for this book is available from the British Library.

Typeset in 10/12pt Minion by Laserwords Private Limited, Chennai, India
Printed in Singapore by Markono

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Astronaut Thomas Reiter works with equipment for a science experiment on board the International Space Station during his second space mission (Source: ESA)

Foreword

Spaceflight - it is hard to imagine another field of engineering science operating so closely at the frontier of our technological capabilities, while at the same time drawing on the resources of so many diverse scientific disciplines. Developing and operating space systems means achieving the lowest possible structural mass at the highest levels of efficiency and reliability under extreme environmental conditions of temperature, radiation and vacuum.

Accordingly, the ability to develop and operate space systems is not only an indicator of the technical, scientific and industrial capacity of an individual country or an alliance of nations, but also a factor which significantly influences its economic competitiveness. Space activities are a powerful propellant for technical innovation.

Today satellite-based communication, navigation and weather forecasting are an integral part of daily life. Global monitoring of our world has become a necessity for studying climate development. Reconnaissance satellites equipped with a wide variety of instruments are as essential for disaster management as they are for establishing an adequate security policy.

A multitude of probes are currently on a journey through outer space and will provide us with new insights in the area of physics and planetary evolution in our solar system. Space activities have already become a much larger part of our lives than many of us realize.

The development challenges described above are especially applicable for the development human space flight systems. There is hardly a terrestrial transport system, no research station, however remote, in which the lives of the people working there are as dependent on the proper functioning and precise interactions of so many subsystems as in a rocket or space station.

From July to December 2006, for almost six months, I had the opportunity to live and work together with an American and a Russian colleague on board the International Space Station. Although our primary task was scientific research in a variety of disciplines, the effort required of us to operate such a station was relatively high. Meanwhile the European Columbus Laboratory went into operation and when the crew is expanded to six people, as planned for mid 2009, it will be possible to considerably increase the capacity to conduct experiments on board the ISS. As far as the design of future human space flight systems is concerned, it will not only be possible to learn a great deal while living and working in the ISS; the station can also be used as a test environment for new technologies or improving existing ones. There is for example the need to improve methods for the analysis, diagnosis, maintenance and repair of on-board systems, the further development of regenerative life support systems, and the testing of innovative propulsion systems.

The major space agencies in West and East are taking the first steps to prepare for a return to the Moon. The question arises of what role Europe will play in these remarkable and inspiring projects. Drawing on its universities, research institutions and industrial capacity, Europe represented by the European Space Agency (ESA) could make a significant contribution to future human spaceflight.

Viewed against the background of Europe's historical development with its wealth of explorers, researchers and scientists, I definitely regard space activities with all their diverse technical, scientific and industrial aspects as a cultural responsibility as well.

I wish all readers of this handbook a pleasurable and rewarding experience, that pinch of intuition which is so often necessary when crossing borders and gaining new insights, and, not least, a very generous portion of curiosity and enthusiasm for their space activities.

Preface

Dear reader,

The first German edition of the *Handbook of Space Technology* was published in 1988, the second 11 years later. Over the past 20 years there have been profound changes in the engineering, materials, processes and even the politics associated with space technologies and their application. As a consequence, the third edition of the handbook, which you find here in its English version, has been entirely rewritten. The editors proceeded in the same way in which they would approach the task of developing a space system: a number of components must be integrated into a system, which is then expected to fulfill its purpose.

So just as with any proper space mission, we begin with the overall objective, the *Mission Statement*:

The *Handbook of Space Technology* is intended to acquaint students, engineers and physicists, as well as readers with a serious interest in space activities, with the design, construction and operation of a space system. This book also leads the way to a deeper understanding of the corresponding specialized areas.

From this *Mission Statement* requirements can be derived. The *Handbook of Space Technology* should:

- be readable as a whole, although it may require some perseverance while also providing adequate insights and information on selected topics;
- present an overview of a space system in its entirety;
- explain the underlying procedures for design, construction and operation;
- contain references connecting separate chapters as an aid to increasing the reader's understanding.

The editors have deliberated on how these requirements could best be fulfilled. They decided in light of their own limitations not to write the book exclusively by themselves. After all, a space system is not built by the system engineer alone; the approach is rather to connect a great variety of components and parts in a meaningful way. Accordingly, we have asked numerous specialists to write various chapters, and in some cases sections within other chapters. These sections contain the expertise of each of these specialists, but also fit into the general concept of this book, fulfilling, as we hope, the *Mission Statement*.

When integrating the various contributions the editors had to tread a narrow path. On the one hand, the book was supposed to be readable as a smooth, unified whole. On the other hand, it was to reflect each author's unique approach to his or her field. In addition, the use of formulas and the significance of diagrams and figures vary in the individual sections and chapters reflecting the characteristic style of the subdisciplines. The character of the individual chapters can serve to assist students in determining their own particular area of interest, and thus provide some orientation for their studies.

The editors would like to use this opportunity to express their heartfelt gratitude to all the authors for their contributions and their patience throughout the editorial process. The list of authors on the following pages links them to individual chapters making evident how much expertise has been involved, and shows to whom we owe our gratitude. It is also intended to give the reader an indication of which experts in Europe can be consulted for further technical information.

The English version is based on the third edition of the German *Handbuch der Raumfahrttechnik* published by Carl Hanser Verlag in 2007. In the translation the book has been brought up to date (2008).

The editors wish to thank the publishers, especially Mr Jochen Horn, for their support. They also thank Mrs Monika Ebke (DLR, Oberpfaffenhofen) for her superb coordination of editors, authors and Carl Hanser Verlag. Last but not least, the editors thank Mrs Susan Giegerich and Dr.-Ing. Joachim Kehr (DLR, Oberpfaffenhofen) for their valuable contributions to the translation of the book. The editors also thank Ms Nicky Skinner, Miss Beth Dufour and Mr Eric Willner of John Wiley & Sons, Ltd for their substantial effort in preparing the English version.

The concept on which this book was based led to the following divisions. Following an introduction with a historical survey and the characterization of mission types in Chapter 1, Chapter 2 presents the fundamental preconditions and principles underlying a space system. Chapters 3 through 7 characterize the segments of a space system, from the transfer segment (Chapter 3) to the space vehicle (Chapter 4) and the

ground segment (Chapter 6) to user applications and payloads (Chapter 7). Several specific features of human space flight are described in Chapter 5. The concluding chapters survey the tasks of the system engineer (Chapter 8) and space flight project management, and address issues of quality assurance and space law (Chapter 9).

The editors' desire to present not only an overview of space systems technology, but also an introduction to the individual technical disciplines resulted in a work of considerable substance. This calls for some effort and patience on the part of the reader. It required the same from the editors, as we found out.

Nonetheless, we hope that the fascination of space can be felt again and again when working with this text, and that this will facilitate reading.

Wilfried Ley, Klaus Wittmann, Willi Hallmann

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