The Scientific Exploration of Mars

What do we know about Mars? What remains to be understood? Is there evidence of life there? Will humans ever travel there?

The dream of exploring Mars has been around since the early days of human civilisation and still forms part of our vision of the future for the human race. Today, we send unmanned spacecraft to explore this neighbouring world to examine its climate, search for evidence of past or present life, and learn how conditions there relate to those on Earth. Plans for a manned mission to Mars recur regularly, set against an uncertain background of political, practical, technical and financial considerations.

This unique book provides a complete description of the past, present and possible future of Mars exploration. Written by a scientist intimately involved with missions to Mars, it provides a personal first-hand account. It will appeal to anyone interested in this fascinating planet.

FREDRIC W. TAYLOR is Halley Professor of Physics at Oxford University, and has spent many years in the Space Science Division of the NASA Jet Propulsion Laboratory, California Institute of Technology. In addition to Mars projects, he has worked on missions to Venus, Jupiter, Saturn and Titan and on Earth observation space experiments. He has received numerous awards and honours, including the Medal for Exceptional Scientific Achievement from NASA and the Bates Medal of the European Geophysical Society for Excellence in the Planetary Sciences.

The Scientific Exploration of Mars

Fredric W. Taylor
Halley Professor of Physics,
University of Oxford

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521829564

First published 2010

Printed in the United Kingdom at the University Press, Cambridge

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data
Taylor, F. W. The scientific exploration of Mars / F. W. Taylor.
p. cm.
ISBN 978-0-521-82956-4 (hardback)
1. Mars (Planet) – Exploration. 2. Mars probes. 3. Space flight to Mars. I. Title.
QB641.T285 2009
523.43–dc22
2009039347

ISBN 978-0-521-82956-4 Hardback

Contents

The plates are situated between pages 50 and 51.

Prologue

Mars is another world in more senses than one. A protective and victorious god, representing both husbandry and war, and the celestial father of Rome; an alternative domain, a 'kind of mythic arena onto which we have projected our Earthly hopes and fears'[1]; a planetary sibling of the Earth that has suffered catastrophic climate change through processes that uncomfortably resemble those now causing concern nearer to home. This book is about the long-term, wide-ranging international scientific research programme that continues to seek to understand Mars, written for non-specialists, such as amateur astronomers or general science readers with an interest in the endeavours, successes and goals of an undertaking that most of us find endlessly fascinating. The aim is to give interested scientists and educated laypersons an intimate view of the science of Mars exploration and its implementation that is as realistic and comprehensive as possible in a readable book of modest size.

The main focus is the current and recent exploration of Mars using spacecraft, which has been pursued by four different national agencies, NASA in the USA, ESA in Europe, RKA in Russia and JAXA in Japan. Others, most notably India and China, say they are preparing to join in. The chapters that follow are a personal perspective on what motivates the scientific community and what it is trying to do, tempered by practical considerations that are often far from obvious to anyone working outside the programmes, not excluding those who report on them in the newspapers and other media. In the later chapters, I seek to take a realistic view of where Mars exploration is heading in the years ahead, in the light particularly of NASA and ESA's plans. These are less vague than those of the other nations who nevertheless will probably participate, or even lead, when the time comes.

There are many books about Mars already, of course, and some are very good. This book aims to be rather different from those, focussing on the *process* of exploring Mars, seeking to pin down the key short- and long-term objectives, and

[1] Carl Sagan, *Cosmos* (1980). Random House, New York.

how progress is made in practical terms, hopefully without being too speculative and unrealistic, nor too technical and specialised. The motivation to explore Mars and expend large sums of money doing so are aired, not to provide justification, but because views on this topic are many and varied, even among supporters and participants. The way in which these are reconciled by governments and agencies determines what exploration shall take place, and when. Few outsiders realise how much work goes into designing missions to Mars and elsewhere that never happen. The politics of space is every bit as hard as the technology when it comes to putting everything together successfully.

An account of such a complex subject is bound to be at least partly subjective. A different author, tackling the same topic, would write a different book. This one is based on a lifetime of studying Mars exploration, from boys' books of science fact and fiction to varying degrees of participation in innumerable NASA and ESA committees and design teams, and in some of the missions that actually flew to Mars, including one that is still active at the time of writing. The events, decisions, missions and scientific progress represented by these, plus the plans and discoveries discussed at conferences and workshops, and the guesses about the future, are based on the work of thousands of people, but are seen through the author's eyes. This is a necessary disclaimer – like all complex activities, from sport to wars, no two people involved will have seen it the same way, only the outcome is beyond dispute.

The perspective in this book comes from nearly four decades of working with and within the NASA programme, starting with ten years at the Jet Propulsion Laboratory, where the Mars work is based, in the 1970s when it all came of age with the hugely successful *Mariner 9* and *Viking* missions. Later, I was there when Europe's first venture to Mars, *Mars Express*, was planned, and for the selection of the payload, including the brilliant but unfortunate *Beagle 2* lander. More importantly for this story, hardware built in our lab in Oxford from 1980 on has been to Mars, no less than three times. The first, on *Mars Observer*, is orbiting the Sun somewhere in the vicinity of Mars, but lifelessly and silently, since that fateful day in 1982 when the spacecraft exploded in an abortive attempt to go into orbit around the Red Planet. The second is on the surface of Mars – most people think that *Beagle 2* was the first British hardware to land there; in fact, the Oxford-built part of the *Pressure Modulator Infrared Radiometer*, an instrument for measuring atmospheric temperatures on NASA's *Mars Climate Orbiter*, was first by nearly five years. Like *Beagle 2*, the *Climate Orbiter* crashed and did not survive. Today there is a new version, *Mars Climate Sounder*, happily circling Mars and taking excellent data at a great rate.

A crucial aspect, little discussed outside specialised meetings and study documents, is the fight to develop the pathways or chains of reasoning that must be followed by the scientific community and the space agencies in setting up a programme of exploration that has the maximum chance of success in achieving stated objectives. The objectives themselves have to be carefully thought through and clearly enunciated, and conflicting opinions and interests resolved. Cost and

resource limitations have to be fully assessed and unexpected difficulties and failures resolved. The logical processes involved are as complex and essential a part of a mission to Mars as the engineering and project management that sends it on its way; I have tried to give the reader a feeling for these topics without getting too much into the (almost literally, sometimes) gory details. Simplified answers to questions about why and how Mars is being explored may not always do justice to a very complex subject, and there is no account that is accurate and complete that is not long, involved and sometimes uncertain. The current situation is evolving rapidly, and all plans for the future are subject to change (indeed, will almost certainly change – there has been considerable evolution, some progressive and some regressive, in the time it has taken to write this book).

The narrative is in three parts. Part I reviews the history of Mars exploration, up to the present day. Then Part II takes stock, asking what is known about Mars as a result of more than a century of serious scientific exploration, and what it is that makes the paymasters – all of us – want to continue. The outstanding scientific questions are conveniently considered under three headings: (1) the origin and evolution of the planetary system, of which Mars and Earth are family members; (2) the processes that regulate the climate and underlie climate change on Earth-like planets; and (3) the search for life outside the Earth. Origins, survival and, for want of a better word, loneliness are the themes. Given these ongoing motivations, Part III looks at the plans for the next steps to be taken that are in the pipeline at space agencies around the world. These are sure to include surface and orbital reconnaissance, subsurface and polar studies, the return of geological samples, at least thinking about manned expeditions, and the omnipresent theme of searching for evidence of life.

Acknowledgements

The story of the exploration of Mars so far, and of ideas and plans for the future, is based on the work of a large number of planetary scientists, aerospace engineers, mission planners and all-round Mars experts toiling in countless study and planning exercises, particularly those of NASA (the American National Aeronautics and Space Administration) and ESA (the European Space Agency). It is impossible to acknowledge everyone involved individually, and if I tried the result would be unreadable, but I do want to express deep thanks to Dr Dan McCleese and the NASA Mars Program team at the Jet Propulsion Laboratory, who hosted much of the work that went into the writing of this book. I would also like to thank colleagues from the various experiment teams and study groups I have worked with for their insights and inspiration: the main ones are listed in an appendix at the end of the book. Several colleagues read all or part of the manuscript in various versions and offered advice; I should like particularly to thank Dr Crofton B. Farmer, Professor Richard Moxon and Vince Higgs for their detailed comment and criticism. Any bias or emphasis placed on facts, probabilities and controversies is of course my own responsibility, as are any errors or exclusions.

Acknowledgements are also due to the originators of figures and artwork reproduced here, and especially to Dr D. J. Taylor for so skilfully drawing the original material used in many of the figures. The remaining illustrations are largely drawn from the projects and planning of the stunningly successful American and European space agencies, as identified from the context and accompanying captions and text. Figures and plates representing futuristic art by commercial artists contain individual acknowledgements and copyright information. Nearly every one of the illustrations in the book is taken or derived from a collection I have made over the last forty years of close observation or involvement in Mars programmes, and is included to invoke what happened then and to add interest and information to the narrative. In a few places where my text may appear to change or embellish the information content as expressed in the original usage, this reflects my own perspective and the responsibility is again mine.

Acknowledgements

The book is dedicated with respect and admiration to the Mars programmes at NASA and JPL, ESA and ESTEC, to all past and present colleagues in the planetary scientific community, and everyone involved in the history of Mars exploration so far. I feel very fortunate to have been around when they made so much of it happen.