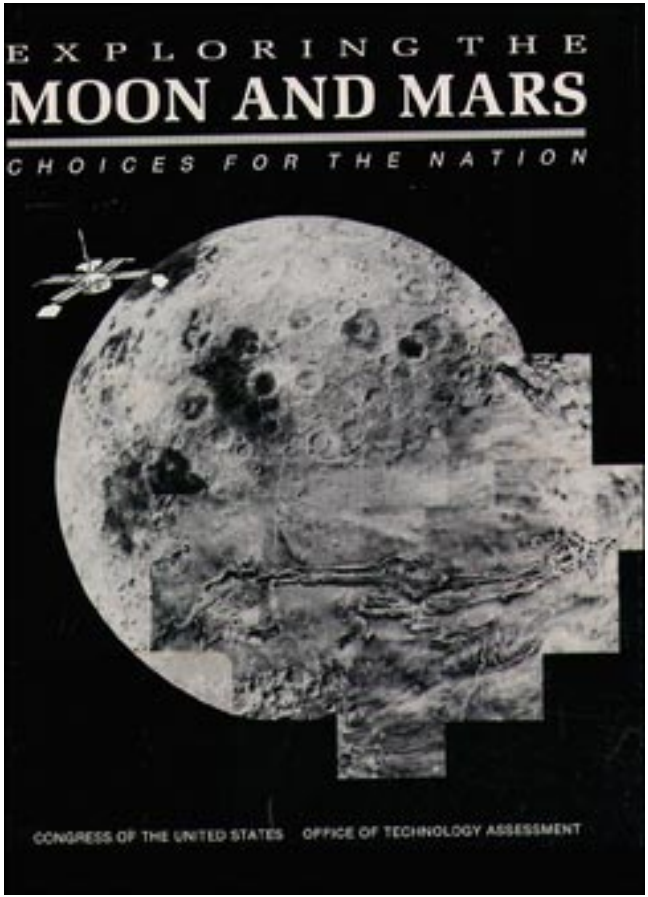
Exploring the Moon and Mars: Choices for the Nation

July 1991

OTA-ISC-502
NTIS order #PB91-220046



Recommended Citation:

U.S. Congress, Office of Technology AssessmenT ***Exploring the Moon andMars: Choices for the Nation, OTA-ISC-502*** (Washington, DC: U.S. Government Printing Office, July 1991).

For sale by the Superintendent of Documents
U.S. Government Printing 0ffice, Washington, DC 20402-9325
(order form can be found in the back of this report)

Foreword

The United States has always been at the forefront of exploring the planets. U.S. spacecraft have now journeyed near every planet in the solar system but Pluto, the most distant one. Its probes have also landed on the Moon and Mars. Magellan, the most recent of U.S. interplanetary voyagers, has been returning thought-provoking, high-resolution radar images of the surface of Venus.

Scientifically, the prospect of returning to the Moon and exploring Mars in greater detail is an exciting one. President George Bush's proposal to establish a permanent lunar base and to send human crews to explore Mars is ambitious and would engage both scientists and engineers in challenging tasks. Yet it also raises a host of issues regarding the appropriate mix of humans and machines, timeliness, and costs of space exploration. This Nation faces a sobering variety of economic, environmental, and technological challenges over the next few decades, all of which will make major demands on the Federal budget and other national assets. Within this context, Congress will have to decide the appropriate pace and direction for the President's space exploration proposal.

This report, the result of an assessment of the potential for automation and robotics technology to assist in the exploration of the Moon and Mars, raises a number of issues related to the goals of the U.S. civilian space program. Among other things, the report discusses how greater attention to automation and robotics technologies could contribute to U.S. space exploration efforts.

In undertaking this report, OTA sought the contributions of a broad spectrum of knowledgeable individuals and organizations. Some provided information, others reviewed drafts. OTA gratefully acknowledges their contributions of time and intellectual effort.

JOHN H. GIBBONS
Director

Workshop on the Robotic Exploration of the Moon and Mars, Feb. 20,1991

Alan Shaw, *Chair*
Manager
International Security and Commerce Program
Office of Technology Assessment

Ronald Brunner
Professor
Department of Political Science
University of Colorado
Boulder, CO

Michael H. Carr
Geologist
United States Geological Survey
Branch of Astrogeology
Menlo Park, CA

Ben Clark
Technical Director
Martin Marietta Corp.
Denver, CO

Lynn Conway
Associate Dean
College of Engineering
University of Michigan
Ann Arbor, MI

Michael Duke
Deputy for Science Lunar and
Mars Exploration Program Office
NASA Johnson Space Center
Houston, TX

Matthew P. Golombek
Research Scientist
Jet Propulsion Laboratory
Pasadena, CA

Noel Hinners
Vice President and Chief Scientist
Civil Space and Communications
Martin Marietta Corp.
Bethesda, MD

Eugene Levy
Chairman
Department of Planetary Science
Lunar and Planetary Laboratory
University of Arizona
Tucson, AZ

Henry Lum
Chief
Information Sciences Division
NASA Ames Research Laboratory
Moffett Field, CA

Carle Pieters
Associate Professor
Department of Geosciences
Brown University
Providence, RI

Paul Spudis
Staff Scientist
Lunar and Planetary Institute
Houston, TX

Alan Stem
Research Scientist
Center for Astrophysics and Space Astronomy
University of Colorado
Boulder, CO

Carol Stoker
Research Scientist
NASA Ames Research Center
Moffett Field, CA

Giulio Varsi
Manager
Space Automation and Robotics program
Jet Propulsion Laboratory
Pasadena, CA

William L. Whittaker
Director
Field Robotics Laboratory
Carnegie Mellon University
Pittsburgh, PA

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the workshop participants. The participants do not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

OTA Project Staff – Exploring the Moon and Mars

Lionel S. ***Johns, Assistant Director OTA***
Energy, Materials, and International Security Division

Alan Shaw, ***International Security and Commerce Program Manager***

Ray A. Williamson, *Project Director*

Conttibutor

Victoria Garshnek, Space Policy Institute, George Washington University

Administrative Staff

Jacqueline R. Boykin
Madeline Gross
Louise Staley

Acknowledgments

This report has benefited from the advice of many individuals from the government and the private sector. OTA especially would like to thank the following individuals for their assistance and support. The views expressed in this report, however, are the sole responsibility of the Office of Technology Assessment.

Arnold D. Aldrich
NASA Headquarters
Washington, DC

Dale Andersen
Lockheed Corp.
Washington, DC

Phillip Ballou
Deep Ocean Engineering
San Leandro, CA

Roger Bedard
Jet Propulsion Laboratory
Pasadena, CA

Geoffrey Briggs
Center for Earth and Planetary Studies
National Air and Space Museum
Smithsonian Institution
Washington, DC

Robert Cannon
Department of Aeronautics and Astronautics
Stanford University
Stanford, CA

Leonard David
Space Data Resources and Information
Washington, DC

Kevin Dowling
Robotics Institute
Carnegie Mellon University
Pittsburgh, PA

Terry Finn
NASA Headquarters
Washington, DC

Herbert Frey
NASA Goddard Space Flight Center
Greenbelt, MD

Peter Friedland
Intelligent Systems Research Division
NASA Ames Research Center
Moffett Field, CA

Louis D. Friedman
The Planetary Society
Pasadena, CA

Stephen J. Hoffman
Science Applications International Corp.
Houston, TX

G. Scott Hubbard
NASA Ames Research Center
Moffett Field, CA

Eric Krotkov
The Robotics Institute
Carnegie Mellon University
Pittsburgh, PA

Louis J. Lanzerotti
AT&T Bell Laboratories
Murray Hill, NJ

Paul Lowman
NASA Goddard Space Flight Center
Greenbelt, MD

Michael Malin
Arizona State University
Tempe, AZ

Harry McCai.n
NASA Goddard Space Flight Center
Greenbelt, MD

Wallace A. McClure
Westminster, CA

Chris McKay
NASA Ames Research Center
Moffett Field, CA

John Menkins
NASA Headquarters
Washington, DC

Lt. Col. Eric Mettala
Defense Advanced Research Projects Agency
U.S. Department of Defense
Washington, DC

David Moore
Congressional Budget Office
Washington, DC

Douglas B. Nash
Jet Propulsion Laboratory
Pasadena, CA

Acknowledgments (continued)

Carl B. Pilcher
NASA Headquarters
Washington, DC

Donna Pivirotto
Jet Propulsion Laboratory
Pasadena, CA

Ian Pryke
European Space Agency
Washington, DC

Don Rea
Mitre Corp.
McLean, VA

Eberhardt Rechtin
University of Southern California
Los Angeles, CA

Sally Ride
California Space Institute
La Jolla, CA

Carl Ruoff
Jet Propulsion Laboratory
Pasadena, CA

Jeffery Rosendahl
NASA Headquarters
Washington, DC

Harrison Schmitt
Albuquerque, NM

David R. Scott
Scott Science and Technology
Los Angeles, CA

Steven Squyres
Cornell University
Ithaca, NY

Delbert Tesar
University of Texas at Austin
Austin, TX

Paul Uhlir
National Research Council
Washington, DC

Jannelle Warren-Findley
Falls Church, VA

Jerry Wasserburg
California Institute of Technology
Pasadena, CA

Dietmar Wurzel
German Aerospace Research Establishment
and German Space Agency
Washington, DC

Maria Zuber
NASA Goddard Space Flight Center
Greenbelt, MD