

Contents

	<i>Page</i>
Chapter 1. Summary	1
INTRODUCTION	1
WHAT IS ROBOTICS?	2
THE HUMAN-ROBOTICS PARTNERSHIP	3
EXPLORATION TIMETABLE	3
MANAGEMENT OF A MISSION FROM PLANET EARTH	4
EXPLORING AND EXPLOITING THE MOON	4
EXPLORING MARS	5
AUTOMATION AND ROBOTICS (A&R) RESEARCH AND DEVELOPMENT	5
COST ESTIMATES	5
INTERNATIONAL COOPERATION AND COMPETITION	6
Chapter 2. Policy and Findings	7
PLANETARY EXPLORATION POLICY AND NATIONAL GOALS	10
THE "MIX" OF HUMAN CREWS AND ROBOTICS FOR EXPLORATION	13
MANAGEMENT OF EXPLORATION	15
RETURNING TO THE MOON	17
EXPLORING MARS	18
A&R RESEARCH AND DEVELOPMENT	21
COST ESTIMATES	24
INTERNATIONAL COOPERATION AND COMPETITION	26
Chapter 3. Human Exploration of the Moon and Mars	29
RATIONALE FOR HUMAN EXPLORATION OF THE SOLAR SYSTEM	29
RISKS TO HUMAN LIFE IN SPACE	35
THE HUMAN-ROBOTIC PARTNERSHIP	35
ROBOTICS SUPPORT OF LUNAR EXPLORATION AND UTILIZATION	37
ROBOTICS SUPPORT OF MARS EXPLORATION	38
STRATEGY FOR EXPLORATION	40
MANAGING THE MISSION FROM PLANET EARTH	41
Chapter 4. Scientific Exploration and Utilization of the Moon	49
UNDERSTANDING THE MOON	49
THE APOLLO PROGRAM	50
THE SOVIET LUNAR PROGRAM	55
SCIENTIFIC OBJECTIVES	55
FUTURE ROBOTICS MISSIONS	57
WORKING ON THE LUNAR SURFACE	61
Chapter 5. Scientific Exploration of Mars	65
UNDERSTANDING MARS	65
CURRENT SCIENTIFIC OBJECTIVES	68
PLANNED AND POTENTIAL ROBOTICS MISSIONS	72
Chapter 6. Automation and Robotics Research and Development	77
AUTOMATION AND ROBOTICS APPLICATIONS	77
SPACE AUTOMATION AND ROBOTICS TECHNOLOGIES	81
TECHNOLOGY ISSUES	84
FUTURE PROSPECTS FOR A&R RESEARCH AND DEVELOPMENT	89
Chapter 7. Costs of the Mission From Planet Earth	91
COST ISSUES	92
PAYING FOR THE MISSION FROM PLANET EARTH	95
Chapter 8. International Competition and Cooperation	97
COMPETITIVE CONCERNS	98
COOPERATIVE OPPORTUNITIES	100

Contents

Boxes

Box	Page
1-A Automation and Robotics for Applications in Space	2
2-A The Flight Telerobotics Servicer (FTS)	23
4-A Scientific Accomplishments of the APO110 program	51
4-B Return to the Moon With Robotic Advanced Sensors: Lessons From Galileo	58
4-C Lunar Observer	60
4-D Advantages and Drawbacks of Using the Moon for Astronomy	62
5-A Findings of Mariner9. "G".o."0""- """"""	66
5-B Findings From the Viking Mars Landers	67
5-C Mars Observer	74
8-A The Inter-Agency Consultative Group (IACG)	102

Figures

Figure	Page
3-1 Summary of Possible Exploration Technology Needs	33
5-1 A View From the Martian North Pole Shows the Location of the TwoViking Sites	71
6-1 Potential Areas for the Application of Advanced Robotics Primary Operations	79
6-2 Potential Areas for the Application of Advanced Robotics Support Operations	80

Tables

Table	Page
2-1 Spending on Civilian Space Activities by the World's Major Industrialized Nations	12
2-2 NASA's Budget for Space Automation and Telerobotics	21
2-3 NASA's Exploration Technology Program	22
3-1 Medical Consequences From Exposure To Space Flight Factors ('Earth Orbit Scenario)	43
3-2 Medical Consequences From Exposure lb Space Flight Factors (Lunar Outpost Mission) (3-day O-G transits, 1/6-G surface stay)	45
3-3 Medical Consequences From Exposure To Space Flight Factors (Mars Mission) (O-G transits, 1/3-G surface stay scenario)	46
3-4 Medical Consequences From Exposure To Space Flight Factors (Mars Mission) (Artificial-G transits, 1/3-G surface stay scenario)	47
3-5 Medical Consequences From Exposure To Space Flight Factors (Mars Mission) (O-G and artificial-G abort scenarios)	48
4-1 Successful Soviet Lunar Missions	50
4-2 Summary of Ranger Missions	52
4-3 Summary of Surveyor Missions	53
4-4 Summary of Lunar Orbiter Missions	53
6-1 Technological Challenges for Intelligent Systems	86