

# Contents

<b>Introduction</b> .....	<b>1</b>
<b>Findings</b> .....	<b>3</b>
<b>The Orbital Debris Environment</b> .....	<b>13</b>
Hazards to space Operations From Orbital Debris .....	13
The Nature of Space Debris .....	15
<b>Sources of Orbital Debris</b> .....	<b>17</b>
Trends .....	21
<b>Debris Reduction Strategies</b> .....	<b>21</b>
Preventive Measures .....	22
<b>Active Removal Procedures</b> .....	<b>23</b>
Shielding and Other Protective Measures .....	25
Geostationary Orbit .....	26
<b>Legal Implications</b> .....	<b>26</b>
The Definition of Orbital Debris .....	27
Jurisdiction and Control .....	29
Detection and Identification .....	30
Liability for Damage Caused in Outer Space .....	31
<b>Future Directions for Reducing Orbital Debris</b> .....	<b>33</b>
Characterization of the Debris Environment .....	34
Mitigation and Protection Techniques .....	36
U.S. Research Plans .....	37
International Cooperation .....	38
<b>Crews in Space</b> .....	<b>40</b>
Special Concerns About Geostationary Orbit .....	41
National Security Concerns .....	42
The Private Sector .....	42
<b>Appendix A Collision Probabilities for Satellites.</b> .....	<b>47</b>
<b>Appendix B U.S. Statutes Governing Outer Space</b> .....	<b>49</b>
<b>Appendix C U.S. Commercial Regulatory Programs</b> .....	<b>51</b>

# Contents

## Figures

<i>Figure</i>		<i>Page</i>
1	Cataloged On-Orbit Population . . . . .	2
2	Orbital Debris Relationships . . . . .	4
3	Yearly Changes to the Cataloged Debris Population . . . . .	13
4	Annual Launch Rate By All Nations . . . . .	14
5	U.S. and U.S.S.R. Contributions to the Orbital Population of Cataloged Objects . . . . .	14
6	Detection Capabilities of the Space Surveillance Network . . . . .	16
7	The Evolution of a Debris Cloud . . . . .	19
8	Relative Kinetic Energy Content of Space Debris Objects . . . . .	20
9	Debris Cataloged from the Breakup of the Transit 4A Rocket Body ..	22
10	Spatial Densities in LEO for Various Sizes of Debris . . . . .	24
11	Total Number of Orbital Objects in the Space Surveillance Network Catalog by Nationality . . . . .	39

## Tables

<i>Table</i>		<i>Page</i>
1	Elements of Orbital Debris . . . . .	2
2	Types of Hazardous Interference by Orbital Debris . . . . .	3
3	Space Weapons Tests . . . . .	19
4	Classes of Space Debris . . . . .	29
5	Key Program Needs for Characterizing the Debris Environment . . . . .	34
6	Spacecraft Surfaces Returned From Space Analyzed for Debris Impacts . . . . .	35
7	Radar Performance Requirements . . . . .	36
8	Key Program Needs for Debris Mitigation . . . . .	37
9	Key Program Needs for Protection From Debris . . . . .	37
10	Phase I Summary of Projected Expenditures for the NASA/DOD/DOT Research Plan . . . . .	38
A-1	Probability of Collision . . . . .	47

## Boxes

<i>Box</i>		<i>Page</i>
1	Some Categories of Earth Orbits. . . . .	2
2	Nine Common Misconceptions About Orbital Debris . . . . .	11
3	Selected U.S. Efforts To Increase Awareness of Orbital Debris . . . . .	14
4	The Evolution of a Debris Cloud . . . . .	18
5	International Space Treaties and Agreements . . . . .	28
6	The Long Duration Exposure Facility (LDEF) . . . . .	35
7	Orbital Debris Radar Observations . . . . .	36