

INTRODUCTION .....	XIII
MEDICAL ROBOTICS AND COMPUTER ASSISTED SURGERY .....	XIII
STUDY BACKGROUND .....	XIII
STUDY GOALS AND OBJECTIVES .....	XIV
INTENDED AUDIENCE .....	XV
SCOPE AND FORMAT .....	XV
METHODOLOGY AND INFORMATION SOURCES .....	XVI
ANALYST CREDENTIALS .....	XVI
RELATED BCC, INC. RESEARCH .....	XVII
RELATED BCC REPORTS .....	XVII
EXECUTIVE SUMMARY .....	XVIII
SUMMARY TABLE U.S. SALES OF MRCAS EQUIPMENT, THROUGH 2007 (\$	
MILLIONS) .....	XVIII
SUMMARY FIGURE U.S. SALES OF MRCAS EQUIPMENT, 1999-2007 (\$	
MILLIONS) .....	XVIII
OVERVIEW OF MEDICAL ROBOTICS AND COMPUTER ASSISTED	
SURGERY .....	1
GENERAL DESCRIPTION AND DEFINITION OF MRCAS .....	1
FIGURE 1 MEDICAL ROBOTIC AND COMPUTER-ASSISTED SURGICAL	
SYSTEMS .....	2
HISTORY OF MEDICAL ROBOTICS AND COMPUTER ASSISTED	
SURGERY .....	3
SURGICAL IMAGING TECHNOLOGIES .....	3
Surgical Imaging Technologies (Continued) .....	4
IMAGE REGISTRATION TECHNIQUES .....	5
COMPUTER IMAGE-PROCESSING .....	6
SURGICAL ROBOTS .....	6
“THE INTELLIGENT OPERATING ROOM” .....	7
SURGICAL SIMULATION .....	8
TECHNOLOGIES AND PRODUCTS .....	8
STAND-ALONE SURGICAL PLANNERS AND SIMULATORS .....	8
Technology .....	9
Modeling of Organs and Deformations .....	9
Simulation of Actions and Force Feedback	
Reactions .....	10
Emerging Technologies .....	11
Web-Based Surgical Simulators .....	11
Virtual Surgery Tables .....	12
Recent Patents .....	12
Advantages of Surgical Planners and Simulators .....	13
Products .....	14
TABLE 1 STAND-ALONE SURGICAL PLANNERS AND SIMULATORS .....	14
Virtual Surgery Table (BARCO Projection Systems) .....	14

Surgical Simulator (Boston Dynamics).....	15
ProMIS (Haptica).....	15
CathSim, Accutouch (Immersion Medical).....	15
SimCor, SimPlanner, SimSuture (SimSurgery).....	16
Procedicus (Mentice Medical Simulation).....	16
LTS2000 (Patton Surgical).....	17
LapSim (Surgical Science).....	17
GI Mentor, URO Mentor, PERC Mentor, LAP Mentor (Simbionix).....	17
SURGICAL NAVIGATION SYSTEMS .....	18
Technologies.....	18
Imaging Technologies .....	18
Multi-Modal Imaging.....	18
Fluoroscopic Imaging.....	19
Video-Enhanced Imagery .....	20
Microscopic Imagery .....	21
Endoscopic Imagery .....	22
Dynamic (Interventional) Imaging.....	23
Compact MRI Scanners.....	23
Intraoperative CT.....	24
Intraoperative Ultrasound.....	24
Tracking Technologies .....	25
Optical Tracking.....	25
Electromagnetic Tracking .....	25
Display Technologies .....	25
Multiplanar Displays.....	26
Three-Dimensional Displays.....	26
Stereoscopic Displays.....	26
Virtual and Augmented Reality.....	27
Heads-Up Displays .....	27
Recent Patents .....	27
Recent Patents (Continued).....	28
Advantages of Surgical Navigation Systems.....	29
Products .....	29
Image-Guided Surgical Navigation Systems .....	30
<i>TABLE 2 IMAGE-GUIDED SURGICAL NAVIGATION SYSTEMS .....</i>	<i>30</i>
VectorVision (BrainLAB AG).....	30
HipNav (CASurgica).....	31
CBYON Suite (CBYON).....	32
InstaTrak, FluoroTrak, ENTrak (GE Medical).....	33
StealthStation Treon, iOn (Medtronic).....	34
Medivision.....	34
Navitrack (Orthosoft).....	34
OTS (Radionics).....	35
VISLAN (Siemens).....	35

	Stryker Navigation System (Stryker Leibinger) .....	36
	Voyager, Z-Box (Z-Kat Inc.).....	36
	Interventional Navigation Systems .....	36
<i>TABLE 3</i>	<i>IMAGE-LESS SURGICAL NAVIGATION SYSTEMS</i> .....	<i>36</i>
<i>TABLE 4</i>	<i>COMPARISON OF NON-FLUOROSCOPIC INTERVENTIONAL IMAGING TECHNOLOGIES</i> .....	<i>37</i>
	OrthoPilot (B. Braun Aesculap).....	38
	PoleStar (Odin Medical Technologies; marketed by Meditronic) .....	38
	SonoDoppler, SonoWand (MISON) .....	39
	CT Guide, US Guide (UltraGuide) .....	39
	Surgical Navigation Accessories and Add-ons.....	39
<i>TABLE 5</i>	<i>SURGICAL NAVIGATION ACCESSORIES AND ADD-ONS</i> .....	<i>40</i>
	Nomad (Microvision).....	40
	OptiVu HDVD (Optimize Corp.).....	41
	Advanced Visualization and Information Management System (Vista Medical Technologies) .....	41
	Pointers, Trackers, Adapters and Other Accessories (4Navitec).....	42
	<b>SURGICAL ROBOTS</b> .....	42
	Technology .....	42
	Robotically-Assisted Micro-Manipulation.....	43
	Steady-Hand Systems.....	44
	Robotic “Wrists” and Other Dexterity Enhancements .....	44
	Pre-Programmed Robots.....	45
	Voice Control .....	46
	Emerging Technologies .....	46
	New Robotic Arm Designs .....	46
	Remote Surgery.....	47
	Natural-Orifice Surgery .....	47
	Microbots .....	48
	Recent Patents .....	48
	Advantages of Robotics.....	49
	Products .....	50
<i>TABLE 6</i>	<i>SURGICAL ROBOTICS</i> .....	<i>50</i>
	ROBODOC (Integrated Surgical Systems).....	51
	NeuroMate (Integrated Surgical Systems).....	51
	DaVinci (Intuitive Surgical) .....	52
	ZEUS (Computer Motion).....	53
	AESOP (Computer Motion) .....	54
	Laprotek (EndoVia) .....	54
	ViaCath (EndoVia).....	54

EndoAssist (Armstrong Healthcare) .....	54
PathFinder (Armstrong Healthcare).....	55
OrthoTrack (Armstrong Healthcare) .....	55
Evolution 1 (Universal Robotic Systems) .....	55
Caspar (Universal Robotic Systems).....	55
“DIGITAL OPERATING ROOMS” AND EQUIPMENT .....	55
Technologies.....	56
Data Routing .....	56
User Interface .....	57
Open Architectures .....	57
Recent Patents .....	58
Advantages .....	58
Products .....	59
<i>TABLE 7 INTELLIGENT OPERATING ROOM SOLUTIONS AND COMPONENTS</i> .....	<i>59</i>
Endosuite “Operating Room of the Future” and endoscopic instruments (Stryker Endoscopy) .....	59
OR 1 (Karl Storz) .....	60
Digital Operating Room and endoscopic instruments (Smith & Nephew).....	60
HERMES (Computer Motion) .....	61
Amsco, 3085 SP Operating Table/Harmony Surgical Lighting System (Steris).....	62
STELLAR Surgical Lighting Systems (Skytron Surgical).....	62
CHROMOPHARE Surgical Lighting Systems (Berchtold Corp.) .....	62
Force FX Electrosurgical Generator (Valleylab) .....	62
PRINCIPAL SURGICAL APPLICATIONS OF MRCAS.....	62
<i>TABLE 8 PRINCIPAL SURGICAL APPLICATIONS OF MRCAS</i> .....	<i>63</i>
ORTHOPEDIC APPLICATIONS .....	63
Hip Replacement .....	64
Knee Replacement.....	64
Trauma.....	65
Pedicle Screw Fixation and Other Spinal Procedures .....	65
Pedicle Screw Fixation and....(Continued) .....	66
NEUROSURGICAL APPLICATIONS .....	67
Stereotactic Biopsy .....	67
Craniotomy .....	67
Shunt.....	68
Implants.....	69
Deep Brain Stimulation .....	69
ENDOSCOPIC APPLICATIONS .....	69
Endoscopic Sinus Surgery .....	70
Other Endoscopic Applications .....	71
GOVERNMENTAL ISSUES .....	72

REGULATORY APPROVAL OF MIS EQUIPMENT.....	72
Regulatory Approval of MIS Equipment (Continued) .....	73
Regulatory Approval of MIS Equipment (Continued) .....	74
REIMBURSEMENT.....	75
Reimbursement (Continued).....	76
THE U.S. MARKET FOR MRCAS EQUIPMENT .....	77
MARKET SIZE AND SEGMENTATION .....	77
OVERALL MARKET SIZE .....	77
TABLE 9 U.S. SALES OF MRCAS EQUIPMENT, THROUGH 2007 (\$ MILLIONS).....	77
MARKET SEGMENTATION BY PRODUCT TYPE .....	77
Summary.....	78
FIGURE 2 MAJOR MRCAS EQUIPMENT SEGMENTS 2002 AND 2007 (PERCENT OF TOTAL SALES) .....	78
TABLE 10 U.S. MRCAS MARKET SHARES BY TYPE OF EQUIPMENT, THROUGH 2007 (\$ MILLIONS AND PERCENT) .....	79
Detailed Market Analysis and Projections .....	79
Surgical Planners and Simulators .....	80
Historical Sales .....	80
TABLE 11 U.S. SALES OF SURGICAL PLANNERS AND SIMULATORS, 1999-2002 (\$ MILLIONS).....	80
Projected Sales .....	80
TABLE 12 PROJECTED U.S. SALES OF PLANNERS AND SIMULATORS, THROUGH 2007 (\$ Millions).....	80
Risk Factors.....	81
Surgical Navigation Systems .....	82
Historical Sales .....	82
TABLE 13 U.S. SALES OF SURGICAL NAVIGATION SYSTEMS, 1999-2002 (\$ MILLIONS) .....	82
Sales Projections .....	82
TABLE 14 PROJECTED U.S. SALES OF SURGICAL NAVIGATION SYSTEMS, THROUGH 2007 (\$ MILLIONS) .....	83
Risk Factors.....	84
Surgical Robots .....	84
Sales .....	84
TABLE 15 U.S. SALES OF SURGICAL ROBOTS, 1999-2002 (UNITS, \$ MILLIONS).....	84
Market Penetration .....	85
TABLE 16 U.S. SURGICAL ROBOT MARKET PENETRATION, 2002.....	85
Projected Sales .....	86
TABLE 17 PROJECTED U.S. SALES OF SURGICAL ROBOTS, THROUGH 2007 (\$ MILLIONS) .....	86
Risk Factors.....	87
Intelligent Operating Room Solutions .....	88
Sales .....	88
TABLE 18 U.S. SALES OF INTELLIGENT OPERATING ROOM SOLUTIONS, 1999- 2002 (UNITS, \$ MILLIONS).....	88
Market Penetration .....	89
TABLE 19 U.S. INTELLIGENT OPERATING ROOM MARKET PENETRATION, 2002.....	89

Projected Sales .....	89
<i>TABLE 20 PROJECTED U.S. SALES OF INTELLIGENT OPERATING ROOM SOLUTIONS, THROUGH 2007 (\$ MILLIONS)</i> .....	89
Risk Factors.....	90
MARKET SEGMENTATION BY TYPE OF APPLICATION .....	90
<i>FIGURE 3 MAJOR MRCAS APPLICATION SEGMENTS, 2002 AND 2007 (PERCENT OF TOTAL SALES)</i> .....	91
<i>TABLE 21 U.S. MRCAS MARKET SHARES BY TYPE OF APPLICATION, THROUGH 2007 (\$ MILLIONS AND PERCENT)</i> .....	92
INDUSTRY STRUCTURE AND COMPETITION .....	92
OVERALL MARKET.....	92
<i>TABLE 22 MAJOR MRCAS VENDORS' U.S. SALES, 2002 (\$ MILLIONS, %)</i> .....	93
<i>FIGURE 4 U.S. MRCAS MARKET LEADERS, 2002 (PERCENT OF TOTAL SALES)</i> .....	93
SURGICAL PLANNERS AND SIMULATORS .....	94
<i>TABLE 23 SURGICAL PLANNER AND SIMULATOR VENDORS' U.S. SALES, 2002 (\$ MILLIONS, %)</i> .....	94
<i>FIGURE 5 U.S. SURGICAL PLANNER AND SIMULATOR MARKET LEADERS, 2002 (PERCENT OF TOTAL SALES)</i> .....	94
SURGICAL NAVIGATION SYSTEMS .....	95
<i>TABLE 24 SURGICAL NAVIGATION SYSTEM VENDORS' U.S. SALES, 2002 (\$ MILLIONS, %)</i> .....	95
<i>FIGURE 6 U.S. SURGICAL NAVIGATION SYSTEM MARKET LEADERS, 2002 (PERCENT OF TOTAL SALES)</i> .....	95
<i>TABLE 25 SURGICAL ROBOT VENDORS' U.S. SALES, 2002 (\$ MILLIONS, %)</i> .....	96
<i>FIGURE 7 U.S. SURGICAL ROBOT MARKET LEADERS, 2002 (PERCENT OF TOTAL SALES)</i> .....	96
INTELLIGENT OPERATING ROOM SOLUTIONS .....	97
<i>TABLE 26 INTEGRATED OPERATING ROOM SOLUTION VENDORS' U.S. SALES, 2002 (\$ MILLIONS, %)</i> .....	98
<i>FIGURE 8 U.S. INTEGRATED OPERATING ROOM SOLUTIONS MARKET LEADERS, 2002 (PERCENT OF TOTAL SALES)</i> .....	98
DISTRIBUTION CHANNELS .....	98
<i>FIGURE 9 U.S. DISTRIBUTION CHANNELS FOR MRCAS EQUIPMENT (PERCENT OF TOTAL SALES THROUGH EACH CHANNEL)</i> .....	99
OUTLOOK FOR THE U.S. MARKET.....	100
DEMOGRAPHIC TRENDS .....	100
TRENDS IN THE INCIDENCE OF CERTAIN DISEASES OR CONDITIONS .....	100
Trends in Cardiac Disease .....	100
Trends in Hip and Knee Replacement.....	101
TECHNOLOGICAL DEVELOPMENTS.....	102
Adaptation of Minimally Invasive Techniques to New Types of Surgical Procedures.....	102
New Products and Technologies .....	102
Development of Lower-Cost Systems.....	103
Increasing Patient Access to Minimally Invasive Surgery.....	103
Facilitating Surgeon Awareness and Training in Minimally Invasive Procedures .....	103

Offsetting Manpower Constraints and Reducing Hospital Labor Costs .....	104
CHANGING STRUCTURE OF THE HEALTH CARE INDUSTRY.....	105
Hospital Consolidation .....	105
Developments in Health Insurance .....	105
CONCLUSIONS .....	105
Conclusions (Continued) .....	106
INTERNATIONAL MARKETS FOR MRCAS.....	107
MARKET SIZE AND SEGMENTATION .....	107
SUMMARY .....	107
<i>FIGURE 10 TRENDS IN THE GLOBAL MARKET FOR MRCAS, 2002 AND 2007 (\$     MILLIONS)</i> .....	107
PRODUCT SEGMENTS .....	108
<i>TABLE 27 U.S. VS. NON-U.S. MARKETS FOR MRCAS DEVICES AND EQUIPMENT     BY MAJOR MARKET SEGMENT, THROUGH 2007</i> .....	108
GEOGRAPHICAL SEGMENTS .....	109
<i>TABLE 28 REGIONAL MRCAS MARKET SHARES, THROUGH 2007 (% MILLIONS)</i> .....	109
U.S. COMPANIES' SHARE OF NON-U.S. MARKETS .....	110
<i>FIGURE 11 U.S. MRCAS VENDORS' SHARE OF NON-U.S. MARKETS, 2002     (PERCENT OF TOTAL NON-U.S. SALES)</i> .....	110
FOREIGN REGULATORY ISSUES .....	111
European Union.....	111
Japan.....	112
Japan (Continued) .....	113
VENDOR PROFILES .....	114
ANAMEDIC (SURGICAL SIMULATION SOFTWARE) .....	114
ARMSTRONG HEALTHCARE LTD. (ROBOTICS).....	114
BARCO PROJECTION (SURGICAL SIMULATION).....	114
BERCHTOLD GMBH (INTELLIGENT OPERATING ROOM EQUIPMENT) .....	115
BOSTON DYNAMICS, INC. (SURGICAL SIMULATORS).....	115
BRAINLAB AG (NAVIGATION SYSTEMS) .....	116
B. BRAUN AESCULAP (NAVIGATION SYSTEMS).....	116
CASURGICA, INC. (NAVIGATION SYSTEMS).....	117
CBYON INC. (NAVIGATION SYSTEMS).....	117
CEDARA SOFTWARE CORP. (NAVIGATION SYSTEMS) .....	117
COMPUTER MOTION, INC. (ROBOTICS) .....	118
<i>TABLE 29 COMPUTER MOTION FINANCIAL PERFORMANCE THROUGH 2001 (\$     MILLIONS)</i> .....	119
CONMED CORP. (INTELLIGENT OPERATING ROOM EQUIPMENT) .....	119
ENDOVIA MEDICAL, INC. (ROBOTICS) .....	119
4NAVITEC GMBH (SURGICAL NAVIGATION ACCESSORIES).....	120

GE MEDICAL SOLUTIONS (NAVIGATION SYSTEMS).....	121
GIVEN IMAGING, LTD. (ROBOTICS) .....	121
HAPTICA (SURGICAL SIMULATORS).....	121
IMAGE GUIDED TECHNOLOGIES, INC. (NAVIGATION SYSTEMS).....	122
IMMERSION MEDICAL (SURGICAL SIMULATORS) .....	122
INTEGRATED SURGICAL SYSTEMS, INC. (ROBOTICS).....	123
INTUITIVE SURGICAL, INC. (ROBOTICS) .....	124
INTUITIVE SURGICAL, INC. (ROBOTICS) (CONTINUED).....	125
<i>TABLE 30 INTUITIVE SURGICAL INC. FINANCIAL PERFORMANCE, THROUGH</i>	
<i>2001 (\$ MILLIONS)</i> .....	126
MEDIVISION.....	126
MEDTRONIC INC. (NAVIGATION SYSTEMS).....	127
MENTICE MEDICAL SIMULATION AB (SURGICAL SIMULATORS) ....	127
MICRODEXTERITY SYSTEMS, INC. (ROBOTICS).....	128
MICROVISION INC. (SURGICAL NAVIGATION ACCESSORIES).....	128
MISON (NAVIGATION SYSTEMS) .....	129
MUSCULOGRAPHICS, INC. (SURGICAL SIMULATION	
SOFTWARE).....	129
OPTIMIZE CORP. (SURGICAL NAVIGATION ACCESSORIES).....	130
ORTHOFT INC. (NAVIGATION SYSTEMS).....	130
PATTON SURGICAL (SURGICAL SIMULATORS).....	130
RADIONICS INC. (NAVIGATION SYSTEMS).....	131
SIEMENS MEDICAL SOLUTIONS (NAVIGATION SYSTEMS).....	131
SIMBIONIX USA CORP. (SURGICAL SIMULATORS).....	131
SIMSURGERY (SURGICAL SIMULATORS) .....	131
SKYTRON SURGICAL INC. (INTELLIGENT OPERATING ROOM	
EQUIPMENT) .....	132
SMITH & NEPHEW PLC (INTELLIGENT OPERATING ROOM) .....	132
STERIS CORP. (INTELLIGENT OPERATING ROOM EQUIPMENT).....	132
KARL STORZ GMBH (INTELLIGENT OPERATING ROOMS) .....	133
STRYKER CORP. (NAVIGATION SYSTEMS, INTELLIGENT	
OPERATING ROOMS).....	133
SURGICAL INSIGHTS INC. (NAVIGATION SYSTEMS) .....	134
SURGICAL SCIENCE AB (SURGICAL SIMULATORS) .....	134
ULTRAGUIDE INC. (NAVIGATION SYSTEMS) .....	134
URS UNIVERSAL ROBOT SYSTEMS (ROBOTICS).....	135
VALLEYLAB (INTELLIGENT OPERATING ROOM EQUIPMENT) .....	135
VEREFI TECHNOLOGIES, INC. (SURGICAL SIMULATION).....	135
VISTA MEDICAL TECHNOLOGIES, INC. (SURGICAL NAVIGATION	
ACCESSORIES) .....	136
<i>TABLE 31 VISTA MEDICAL TECHNOLOGIES INC. FINANCIAL PERFORMANCE,</i>	
<i>THROUGH-2001 (\$ MILLIONS)</i> .....	136
Z-KAT INC. (NAVIGATION SYSTEMS) .....	136
APPENDIX .....	137



PROFESSIONAL ASSOCIATIONS.....	137
PROFESSIONAL ASSOCIATIONS (CONTINUED) .....	138