Robotic Assisted Surgery Landscape Review

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FSI Introduction and Scope of the Report

About Fletcher Spaght, Inc.

FSI is a Boston-based healthcare and life sciences strategy consulting and advisory firm that helps clients grow with rigorous analysis and tactical growth action plans.

Our firm has broad and deep expertise in healthcare with nearly 40 years working with companies and investors on growth strategy, business planning, and investment diligence.

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Details and Scope of This Report

This report highlights the analysis of the Robotic Assisted Surgery (RAS) Landscape in 2022.

Included are development stage and funding status of RAS platforms in key segments, including surgical platforms and positioning/navigation-enabled platforms, as well as global market size, market trends, and healthcare investments*.

*Development stage, funding status, and investments as of Dec 31, 2022

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Robotic Assisted Surgery (RAS) market is ~$9B, expected to grow 7% annually; RAS VC investment peaked in 2021, reaching $1.8B

Robotic-assisted surgery market is projected to grow from ~$9B in 2022 to ~$16B in 2030 (7% CAGR)

- North America comprises the majority of the market at 68%; all markets projected to grow at CAGR of ~7%
- Laparoscopy represented 76% of the market in 2022, expected to drop to 70% in 2030
  - Orthopedic and neurosurgery markets expected to grow faster than laparoscopic surgery for both surgical systems and system accessories

The number of VC investments and deals in the RAS space has grown over the last few years

- VC investment increased from $0.2B in 2017 to $1.8B in 2021; 2022 investment of $0.8B is closer to pre-pandemic levels
- Large MedTech players are strengthening their position through M&A (Carl Zeiss acquired Preceyes, J&J acquired Auris, Stryker acquired Mobius Imaging & Cardan Robotics)

Market drivers include:

- Emergence of new players in the market
- Expansion of procedures performed robotically (e.g., microsurgery, endoluminal)
- Shift in procedures from in-patient to out-patient settings creating opportunities for portable, modular, and lower-priced robots
- Increasing adoption and integration of advanced technology such as AI/ML with robotic systems

Source(s): GlobalData, Pitchbook

RAS platforms with regulatory approval or $5M+ in funding

Robotic Surgery (128) [1,2]

- **Surgical Platforms (58)**
  - **MIS (46)**
    - **Laparoscopy (34)**
      - Surgical Assistance (28)
      - Positioning Assistance (6)
    - **Endoluminal (12)**
      - INTUITIVE SURGICAL®
  - **Microsurgery (12)**
    - **Surgical Assistance (9)**
    - **Positioning Assistance (3)**
      - ZEISS
- **Positioning / Navigation-enabled Platforms (70)**
  - **Hard-tissue (32) [3]**
    - Bone Cutting (19)
    - Screw Placement (12) [3]
    - Passive Leg Support (1)
      - stryker
  - **Soft-tissue (26) [3]**
    - Needle / Probe Positioning (17) [3]
    - Ablation (9)
      - ZIMMER BIOMET — Your progress. Our promise.®
  - **Vascular Navigation (13)**
    - Corindus — A Siemens Healthineers Company

110 unique companies offer 128 platforms

- 96 companies have one platform
- 10 companies have two platforms
- 4 companies have three platforms

Notes: Number in parenthesis indicates the number of platforms in the space.

[1] Multiple platforms in the same sub-category but different specialty are counted once; however, platforms in different sub-categories are counted separately (*e.g.*, Corin Group has two separate platforms addressing bone cutting (hip replacement and knee replacement) which are counted once. Curexo has CUVIS-Joint 150 for bone cutting and CUVIS-Spine for screw placement which are counted separately). [2] Does not include Cornerstone robotics which is very stealth and has not been further categorized; [3]Globus Medical has one platform for Screw Placement and Needle / Probe Positioning

58 total Surgical Platforms, 30 with regulatory approval; Laparoscopy a crowded segment with 34 platforms

Stage of Product	Laparoscopy	Endoluminal	Microsurgery
FDA clearance / approval	Asensus Surgical; Human Xtensions; Dex Surgical; Medrobotics; Momentis Surgical; Intuitive Surgical; freehand; Moon Surgical; AKTORmed Robotic Surgery	EndoTools Therapeutics; Intuitive Surgical; J&J	Venus Concept; Zeiss; synaptive; iotamotion
OUS regulatory approval	Medtronic; CMR Surgical; Distalmotion; Riverfield; meere company; Medicaroid; Edge Medical 精锋医疗; SS Innovations; MicroPort; avatera		microsure; Cascination; MMI Microinstruments; Zeiss
US clinical trials	Virtual Incision	Endoquest Robotics	
OUS clinical trials	Levita Magnetics; Great Robotics; 术锐 Shurui; Wego Ortho 威高骨科	MicroPort; Robo; EndoMaster	
In-development	Titan Medical; Riverfield; USMI US Medical Innovations; J&J; Asahi Surgical Robotics; 佗道医疗 Tuodao Medical; Panther Healthcare 派尔特医疗; Borns; rob surgical; Vicarious Surgical	Virtuoso Surgical; Noah Medical; rm tech 元化; Caranx Medical; Agilis Robotics	Acusurgical; Forsight Robotics; Riverfield; Galen Robotics

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

70 total Positioning / Navigation-enabled Platforms, 45 with approval; Vascular Navigation ripe with development pipeline

Stage of Product	Hard tissue	Soft tissue	Vascular Navigation
FDA clearance / approval	NUVASIVE, Medtronic, THINK SURGICAL, MicroPort, POINT, J&J, ecential robotics, Accelus, neocis, BRAINLAB, ZIMMER BIOMET, GLOBUS MEDICAL, stryker, Corin, CUREXO, smith&nephew	ZIMMER BIOMET, ACCURAY, MONTERIS MEDICAL, QUANTUM surgical, edap tms, CASCINATION, ACOUSTIC MEDSYSTEMS, PROCEPT BioRobotics, XACT Robotics, biobot, Dominion Aesthetic Technologies, GLOBUS MEDICAL, INSIGHTEC, RENISHAW	STEREOTAXIS, Corindus
OUS regulatory approval	长木谷, CUREXO, TINAVI 天智航, rm TECH 元化, Remebot, AOT Advanced Osteotomy Tools	NDR Medical Technology, THERACLION, BRAIN NAVI, Remebot, SS INNOVATIONS, Perfint, Soteria Medical	Robocath
US clinical trials		HISTOSONICS	
OUS clinical trials	LONGWELL, Jianjia Robots, ROSSUM ROBOT		奥朋医疗
In-development	caira, amplitude SURGICAL, 佗道医疗 TUODAO MEDICAL, monogram, MASMEC BIOMED, CYBERDONTICS	CLEARPOINT NEURO, neuro42, ZETA SURGICAL, 佗道医疗 TUODAO MEDICAL	RainMed, Catheter Precision, medipixel, Artedrone, EndoWays, GREAT ROBOTICS, microbot medical, MORAY MEDICAL, Xcath

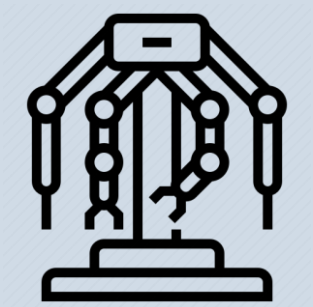
>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

Large medtech and health system executives are in alignment about the future of surgical robotics

Large medtech executive view
on the future of surgical robotics

- Robotic surgery will become available to sites of care beyond the hospital inpatient setting
- Advancements in artificial intelligence will propel automation of robots to reduce cognitive load, variability, and error in surgery
- Robotic systems will complement and be integrated into digital surgery ecosystems to help before, during, and after the procedure
- Intelligent robotic systems will become ubiquitous in surgery



Health system executive view
on the future of surgical robotics

- More out-patient surgeries will be the norm especially with capacity constraints
- Hospitals will look to increase standardization to reduce unwanted variability
- Adoption of robotic platforms will to be driven by data (*e.g.,* reduced mortality, reduced complications, improved length of stay, improved satisfaction, increased volume, and cost-effectiveness)
- Providers will view and manage robotic surgery as a service line to maximize ROI

Several key opportunities for selling and innovating within surgical robotics exist as the market evolves

Challenges	Opportunities for Companies
Commercial	
Cost structures and economics (*e.g.,* reimbursement) around robotic surgery have remained a major obstacle to widespread adoption	Innovative business models will be an impactful differentiator (*e.g.,* pay-per-use, leasing models); drive value-based care for improved reimbursement (*e.g.,* only reimbursed if lung biopsy platform successfully obtain a biopsy)
Post-COVID budgets are tight and staffing problems are persistent	Frame value propositions in terms of what hospitals / key decision makers care most about – hospital executives need data to support ROI
Surgeons may see robots as unnecessary – they are talented and experienced clinicians	Use robots as a tool to address clinical needs described by physicians rather than implementing robotics for the sake of having a robot
Innovating	
Hardware innovation has become relatively incremental	Leveraging patient and physician data to help validate value propositions and create revolutionary intelligent systems
Outcomes data regarding robotic-assisted surgery have not been highly convincing	Systems that enable post-operative monitoring may help validate key outcome improvement claims (*e.g.,* 'smart' implants and remote patient monitoring that leverage data collected by RAS systems and housed in EMRs)
Many systems aim to impact specific step(s) within a procedure	Seek to add value to as many steps of a procedure, or as many procedure types, as possible to strengthen value propositions and distribute costs
The large footprint of existing robotic systems require dedicated ORs / significant OR redesigns and staff trained on the highly complex machines	Smaller footprint, simpler, modular designs to attract out-patient facilities; easier-to-use systems especially with staffing shortages (Intuitive has captured significant AMC / large health system share in the US)

Burgeoning data/AI systems and under-served clinical needs provide potential RAS investment opportunities

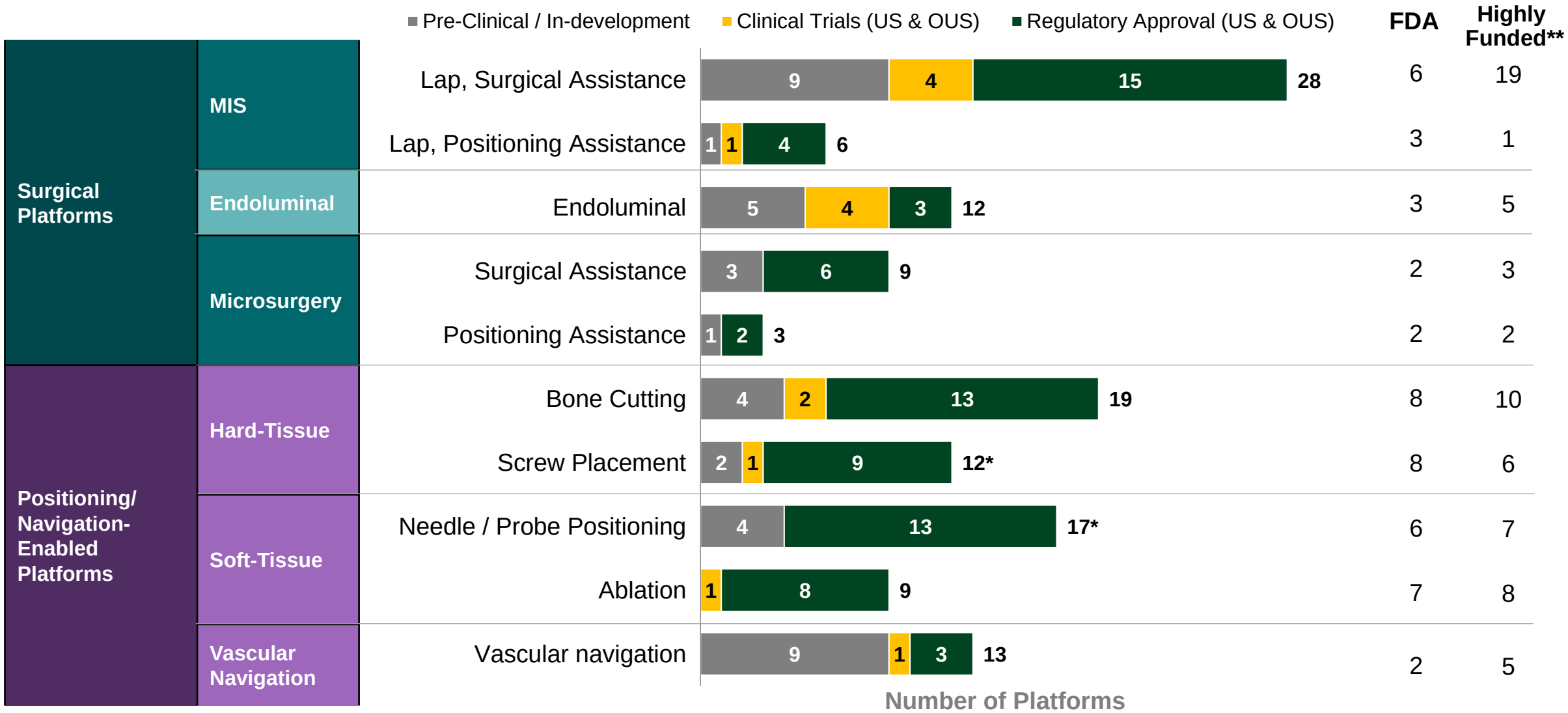
Challenges	Opportunities for Investors
Data, Artificial Intelligence, and Automation	
Outcomes data regarding robotic-assisted surgery have not been highly convincing	Data-heavy companies may be better positioned to “prove out” their value proposition faster with patient/surgeon-specific data, and cloud-based systems
Many platforms may not be leveraging intelligent or automated processes to their full potential	Intelligent systems (AI, automation, AR/VR) are the future of robotic surgery and will allow for personalization for clinicians and patients, reducing cognitive load and driving standardization across procedures
Surgical Platforms have already achieved significant regulatory approvals both OUS and in the US – hardware tech is likely nearing saturation	Differentiation in an increasingly saturated segment will stem from what data is captured and how it is leveraged to improve outcomes and reduce costs
Segments of Interest	
Laparoscopic MIS Surgical Platforms already have well-established market presence and are dominated by large strategics	Endoluminal MIS Surgical Platforms are gaining momentum as providers seek to be as minimally invasive as possible; less saturated segment than laparoscopic systems
Within Positioning / Navigation-enabled Platforms**,** Hard-tissue and Soft-tissue systems have already seen numerous regulatory approvals from both large strategics and small companies	A potentially significant opportunity exists within Vascular Navigation as the field has only seen two US approvals with many systems in development
Lack of approved Microsurgery platforms in the US, especially in open microsurgery and ophthalmology	Microsurgery represents a potential “next frontier” for RAS with relatively low competition US and OUS across specialties; no ophthalmology or open microsurgery robots yet in the US
With so many companies competing for market share across numerous indications, hospitals may be overwhelmed by siloed options	Collaboration with larger strategics to create clinical ‘ecosystems’ that span multiple specialties can allow a hospital’s investment to be spread over more procedures and provide granular traceability for value-based care models

Platforms aim to win by offering clinical, operational, and economical advantages over existing systems

	Clinical	Operational	Economical
Surgical Platforms	Provides better control during laparoscopic procedures; aims to reduce the number of incisions required to speed up recovery	Levita Magnetics	GALEN ROBOTICS: Innovative business model offering robot as a service to reduce the cost of ownership; aim to provide best practice guidance to surgeons based on data from experts
	VIRTUOSO SURGICAL: Provides advantages of robotic assistance and improves control for endoscopic surgery leading to improved outcomes		VIRTUALINCISION: Small (2lb) bed-side robot that is procedure specific; expands the number of patients that can benefit from robotic surgery
Positioning / Navigation-enabled Platforms	HISTOSONICS: Non-invasive treatment for cancer that aims to improve clinical outcomes	NDR Medical Technology: AI uses CT images to automate lesion detection and needle path planning to offers multiple possible paths allowing surgeons to choose the optimal trajectory	neuro42: Combining portable MRI and surgical robotics to improve access to care
	monogram: Provides robotic surgery with personalized 3D printed implant to improve clinical outcomes	CYBERDONTICS: Aims to bring robotic guidance for root canal while reducing procedure time and number of visits	caira: Claims 5x reduction in set-up time and 10x improvement in equipment cost
	TINAVI 天智航: Robot for pedicle screw placement capable of covering multiple applications (spine, pelvis, hand, ankle, hip, and shoulder)	ZETA SURGICAL: Provides marker-less registration leveraging computer vision to eliminate a step	MORAY MEDICAL: Provides single hand operation for mitral valve repair and reduces the need for an assistant physician

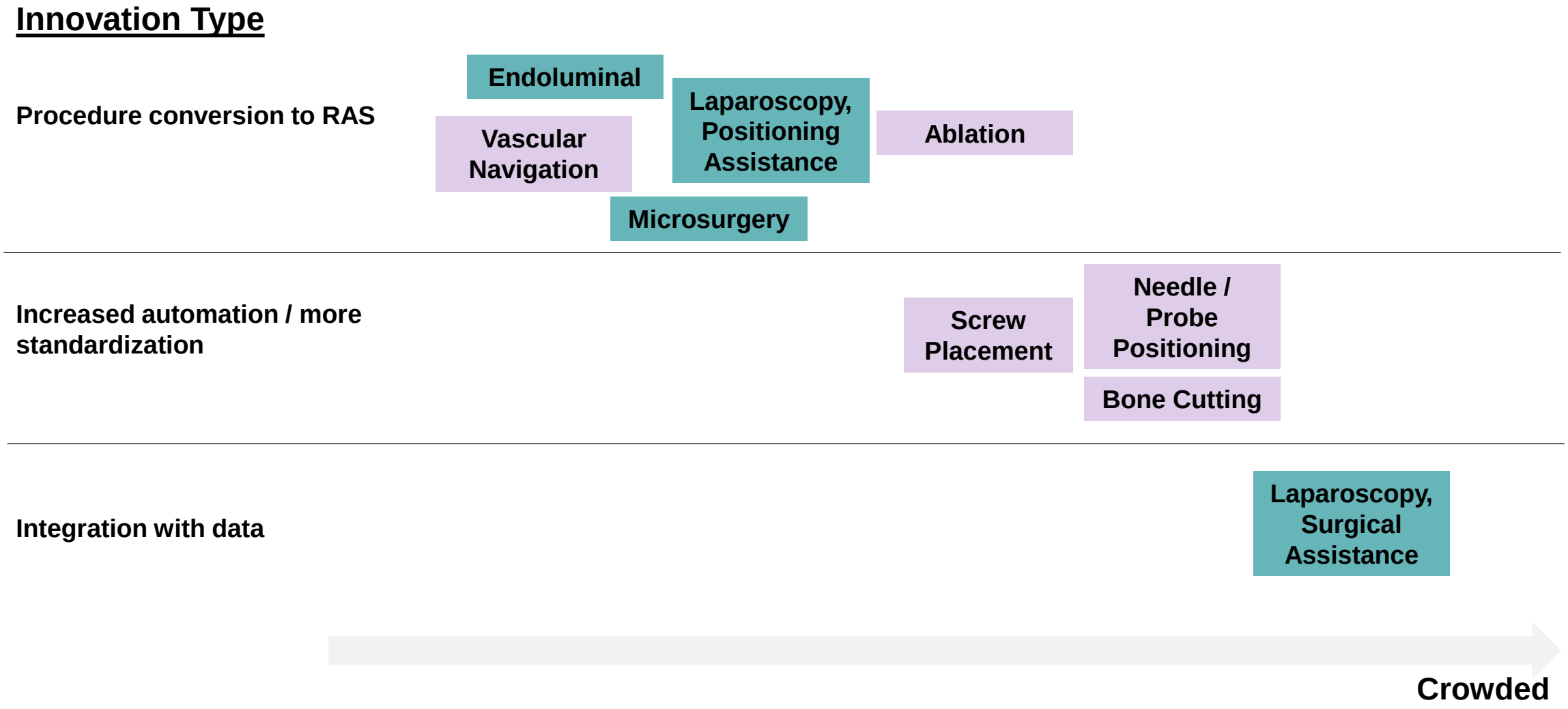
Not an exhaustive list

59% of platforms have regulatory approval, 11% are undergoing clinical trials, and 30% are pre-clinical/in-development



*Globus Medical has the same platform for screw placement and needle / probe positioning but counted under both categories; **Funding >$50M or public companies (US or OUS)

Less crowded spaces aim to bring benefits of RAS to more procedures; crowded spaces aim to increase automation and integrate with data



Microsurgery has relatively fewer regulatory approvals and presents opportunities for early investment; MIS space crowded

Category	Sub-category	Opportunities for Early Investment
MIS	**Laparoscopy, Surgical Assistance**	• Crowded space with 28 platforms where 16 have regulatory approval • Hardware differentiators are incremental to existing platforms presenting limited room for investment unless companies begin to leverage data in meaningful ways
	Laparoscopy, Positioning Assistance	• 6 platforms where 4 have regulatory approval • Could negatively impact the surgical assistance market by making conventional laparoscopy easier • May appeal to surgeons not convinced about benefits of robotics, as well as those who are cost-sensitive
	Endoluminal	Endoluminal laparoscopic • 8 platforms in the space but only 1 platform has regulatory approval • Directly compete with surgical assistance platforms and may take share by offering smaller foot-print robots at a lower cost. Also, provide a scarless option which may be appealing to patients Bronchoscopy/Ureteroscopy • 4 platforms in this space and 2 have regulatory approval • Companies with in-development platforms aim to improve diagnostic yield of lung biopsy • Existing players strengthening position with plans to offer therapy and expand indications (*e.g.*, J&J received FDA clearance for urology in May 2022 and plans to complete a first-in-human study)
Microsurgery	**Surgical Assistance**	• 9 platforms addressing various indications. Only 2 have FDA approval, but none addressing open microsurgery or ophthalmology have US regulatory approval • Provides opportunities for early investment as it is a growing field with low competition especially in the US • Companies planning to leverage data and offer innovative business models
	Positioning Assistance	• Only 3 platforms in this space with 2 platforms that have regulatory approval • Limited opportunities for investment

High level of innovation in Bone Cutting, Needle Positioning, & Vascular Navigation presents investment opportunities

Category	Sub-category	Opportunities for Early Investment
Hard-tissue	**Bone Cutting**	• 19 platforms where 13 have regulatory approval • Has 4 major players in this space but pre-clinical platforms aim to offer significant clinical, economical, and operational benefits over existing systems • New applications such as dental robotics are emerging
	Screw Placement	• 12 platforms with 9 players that have regulatory approval • Early-stage platforms not highly innovative providing limited opportunities for investment
Soft Tissue	**Needle / Probe Positioning**	• 17 platforms where 13 have regulatory approval including major players • 4 platforms are pre-clinical / in-development and 2 new players are highly innovative
	Ablation	• 7 of 9 platform have FDA clearance / approval with no major players indicating a fragmented market • Field is highly innovative with new types of therapy that are delivered non-invasively, but limited opportunities for investment as platforms have FDA clearance or high-level of funding
Vascular Navigation	**Vascular Navigation**	• 13 platforms in this space where 9 platforms are under development • High potential for early-stage investment as platforms are addressing various applications

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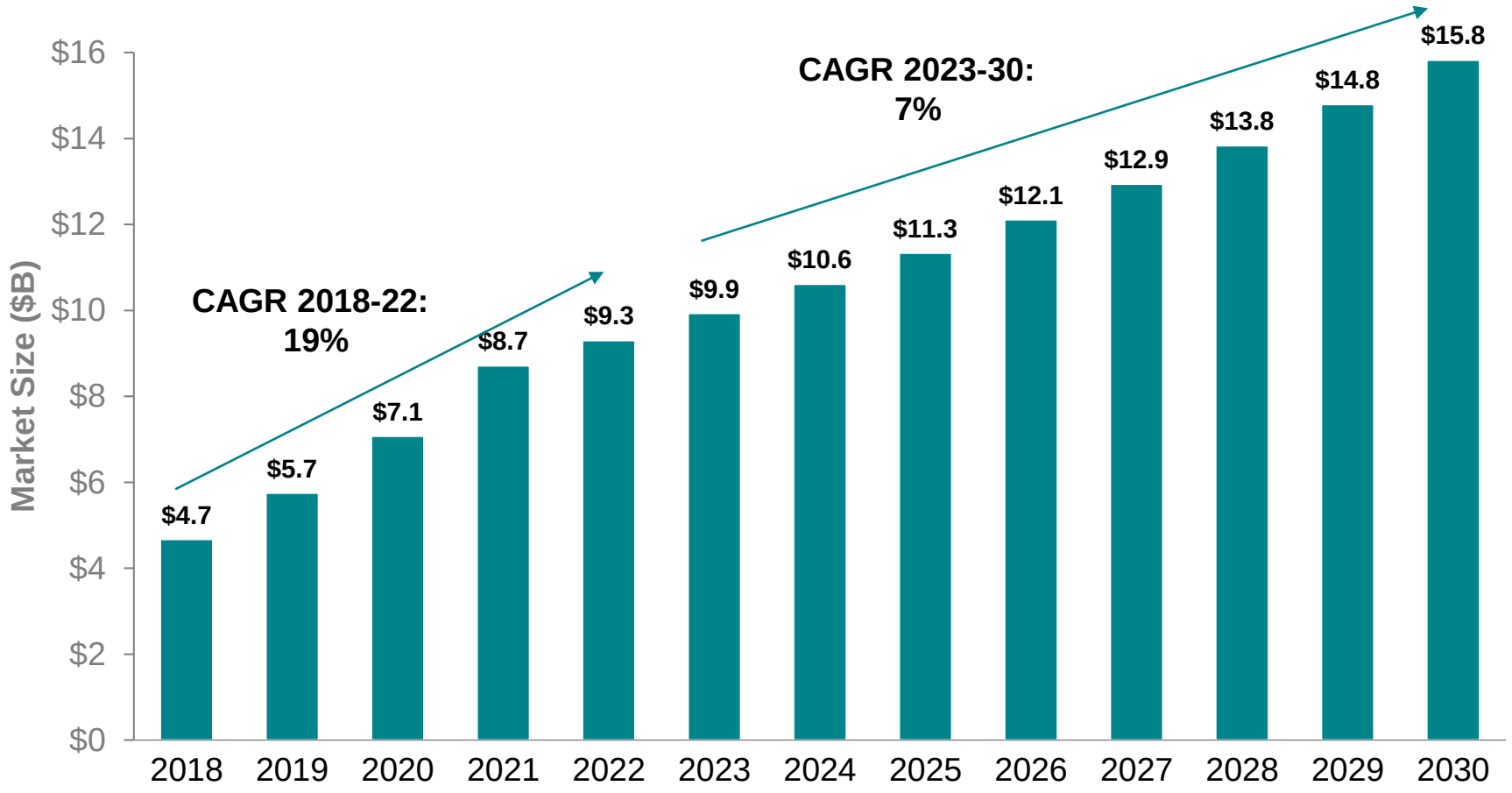
Robotic Assisted Surgery Market expected to grow with a CAGR of 7%

Robotic Assisted Surgery Market Size

2018-2030

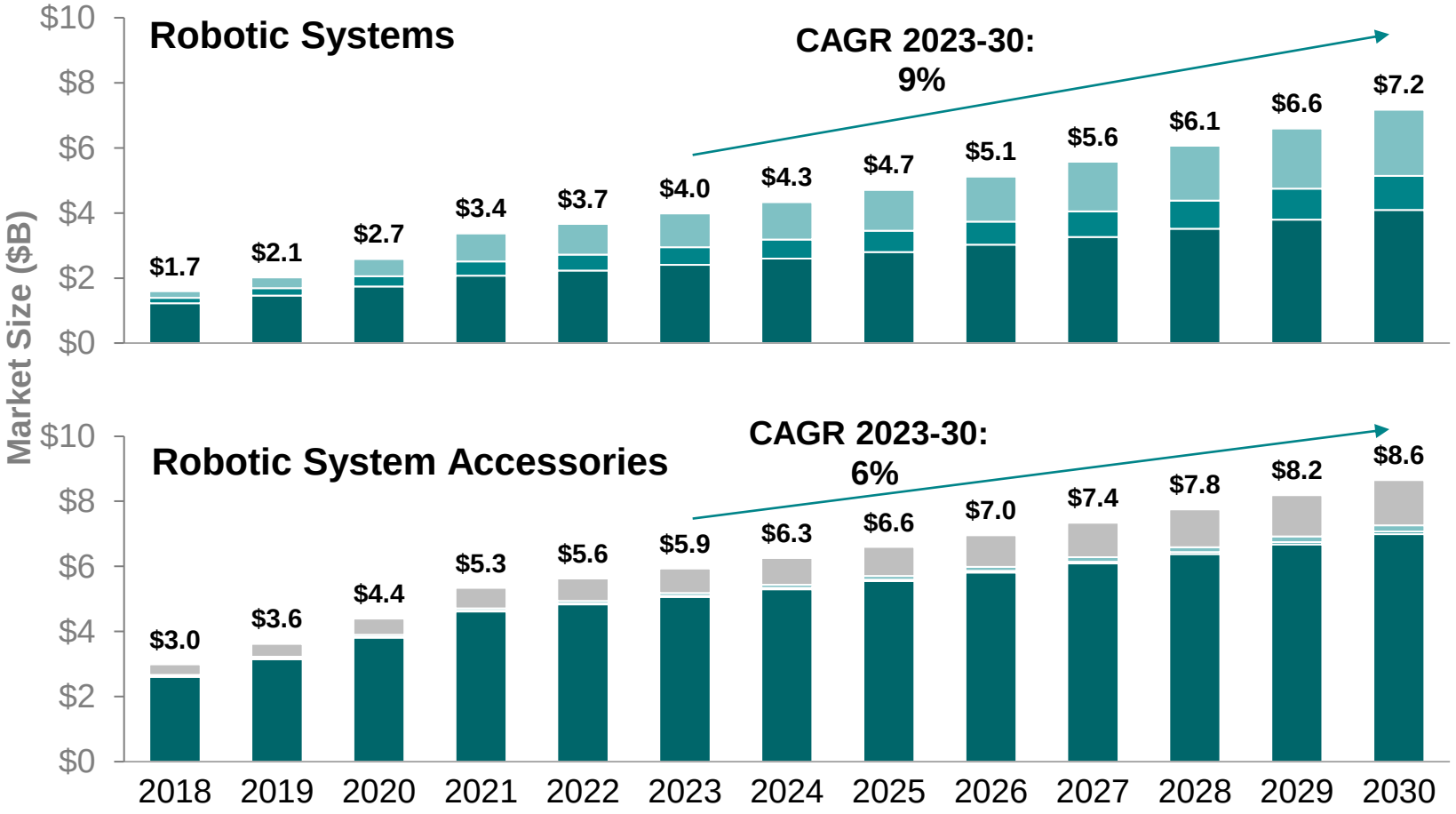


Source: GlobalData; Note: Includes Robotic Surgical Systems and Accessories

Orthopedic and neurosurgery robotic assisted surgery markets are expected to grow quicker than laparoscopy

Robotic Assisted Surgery Market Size

2018-2030



Systems	CAGR 2018-22	CAGR 2023-30
Orthopedic	47%	10%
Neurosurgery	30%	10%
Laparoscopy	16%	8%

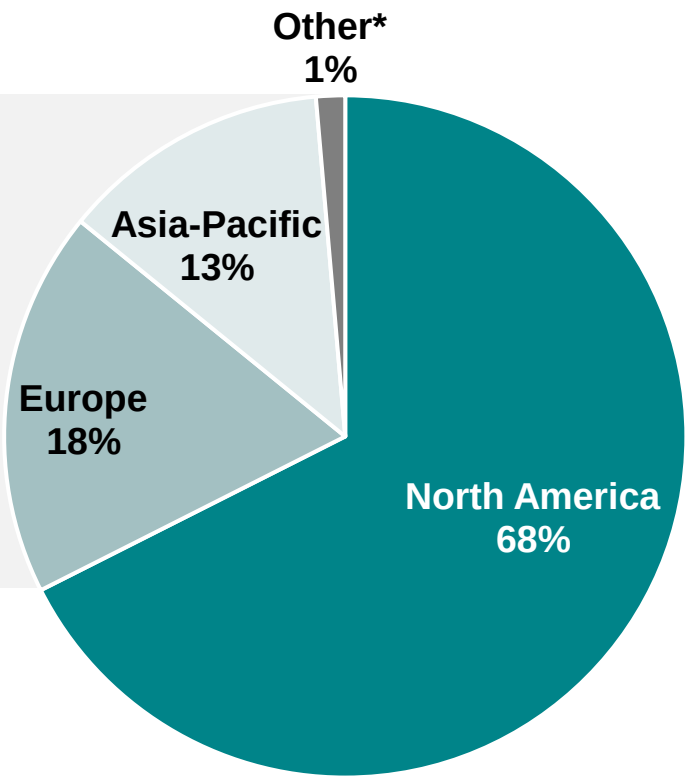
Accessories	CAGR 2018-22	CAGR 2023-30
Misc. Disposables	21%	9%
Orthopedic	14%	11%
Neurosurgery	17%	13%
Laparoscopy	17%	5%

Source: GlobalData; Note: Includes Robotic Surgical Systems and Accessories

North America comprises the majority of the market at 68%; all markets projected to grow ~7% annually

Market Share by Geography (2021)

FSI Opinion: OUS spending patterns tend to be more resource-constrained and frugal in comparison to the US; likely a factor in lower market penetration OUS

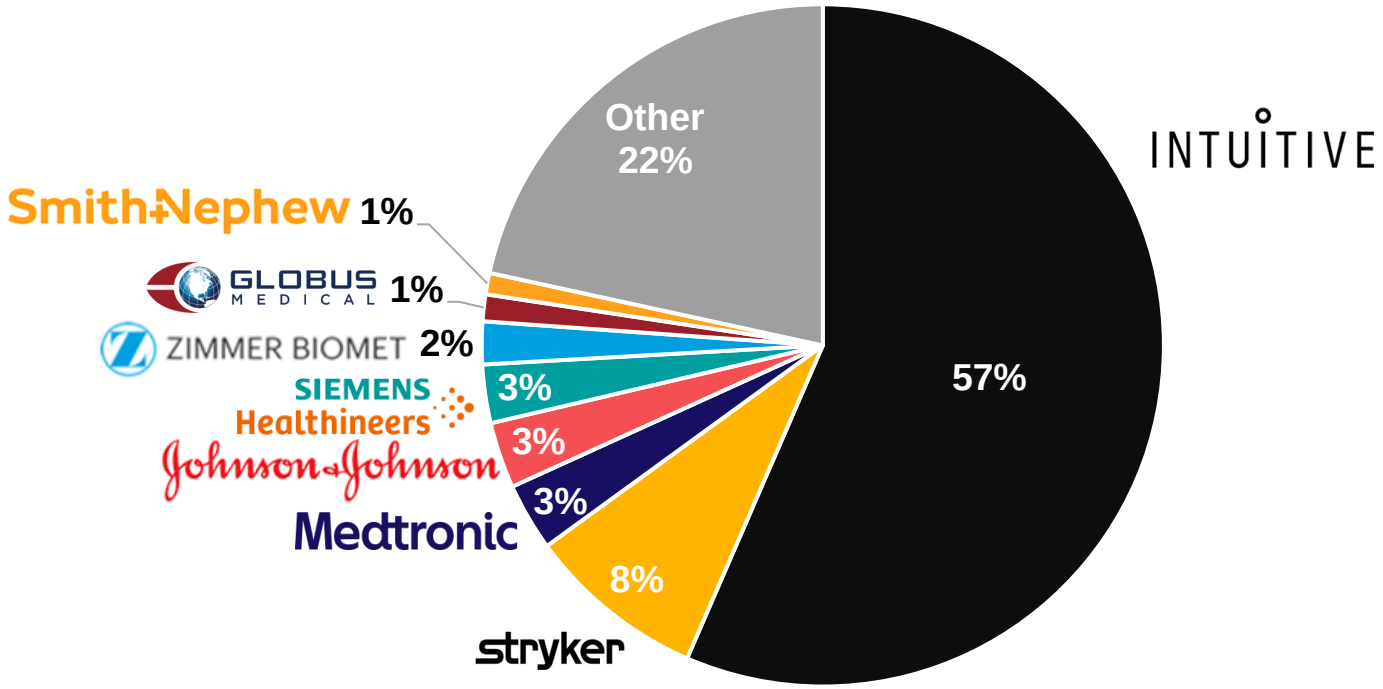


Country	CAGR 2018-22	CAGR 2023-30
North America	22%	7%
Europe	15%	8%
Asia-Pacific	14%	7%
Other	17%	7%
Overall	19%	7%

Source: GlobalData. *Other includes Middle East, Africa, South & Central America

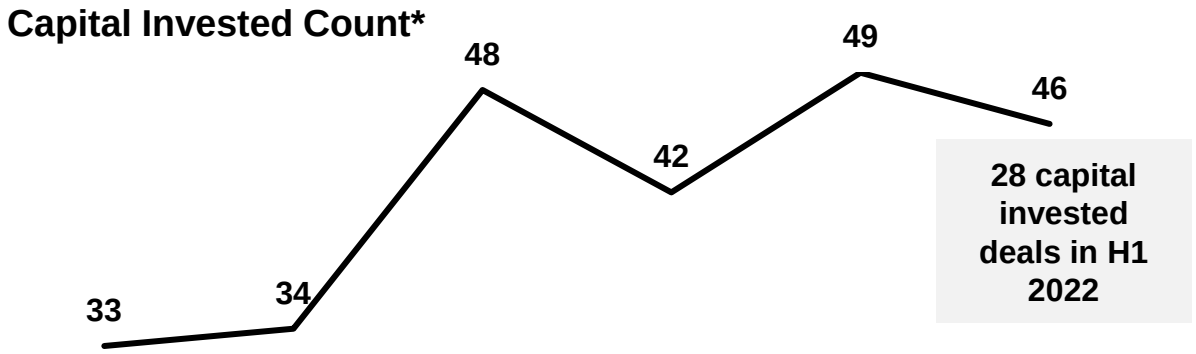
Intuitive holds 57% of the market; the remainder is highly fragmented

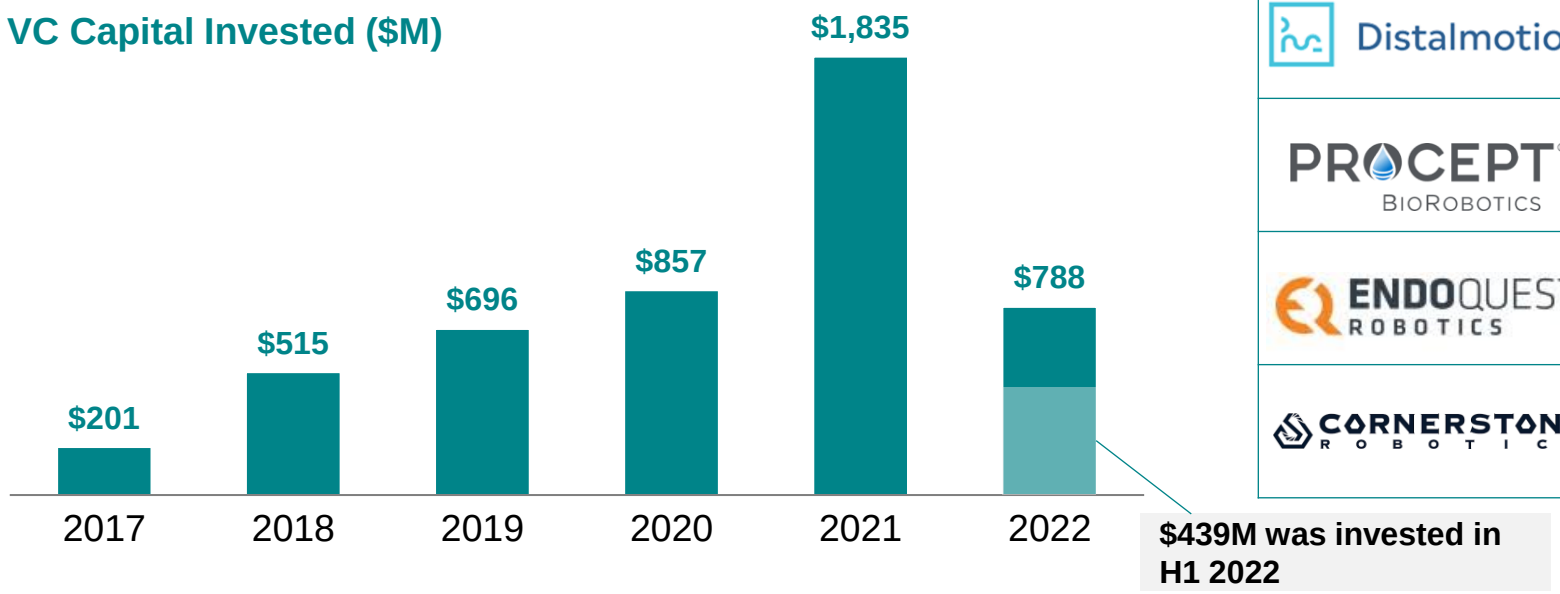
Market Share by Key Players (2021)



Source: GlobalData *Other includes companies with <1% share, other manufacturer revenues, and third-party revenues

2021 was an unprecedented year, with $1.8B in VC investments; 2022 returned closer to pre-pandemic levels





Top VC Deals between 2021 to 2022 (YTD)		
CMR SURGICAL	$600 M Series D, Late-Stage	Jun-2021
Noah Medical	$150 M Series B, Early-Stage	Jan-2022
Distalmotion	$90 M Series E, Late-Stage	Jan-2022
PROCEPT BioRobotics	$85 M Series G, Late-Stage	Jun-2021
ENDOQUEST ROBOTICS	$76 M Series C, Late-Stage	May-2021
CORNERSTONE ROBOTICS	$76 M Series B, Early-Stage	Nov-2021

Source: Pitchbook. *Capital Invested Count refers to the number of funding rounds with a known capital invested value in the Pitchbook database.

Large MedTech players strengthened their position in robotics through M&A over the last five years

Acquirer	2017	2018	2019	2020	2021	2022
Medtronic		Mazor Robotics		Digital Surgery™		
Johnson & Johnson		ORTHOTAXY	AURIS™			ABIOMED*
SIEMENS Healthineers			Corindus Vascular Robotics			
stryker			Mobius IMAGING			
INTUITIVE		UNISON SURGICALS 信文達股份有限公司	Schölly EXCELLENCE INSIDE			
ZEISS CARL ZEISS MEDITEC						PRECEYES
GLOBUS MEDICAL	KB MEDICAL					
Surgalign				HOLOSURGICAL		
surgicalscience					mimic	

Sources: Pitchbook, Refinitiv. *Note: Abiomed has a vascular platform known as Impella, which includes a steerable catheter providing positioning feedback & heart pumping

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Industry Executives on the Future of Robotics in Surgery

Intelligent, data-driven solutions will drive robotics to become ubiquitous in surgery

Key Themes
Robotic surgery will become available to sites of care beyond the hospital in-patient setting
Advancements in artificial intelligence will propel automation of robots to reduce cognitive load, variability and error in surgery
Robotic systems will complement and be integrated into digital surgery ecosystems to help before, during, and after the procedure
Intelligent robotic systems will become ubiquitous in surgery

Sources: CNBC Interview with Joaquin Duato; MedGadget Interview with Tracy Accardi; Device Talks Interview with Gary Guthart; Medium Interview with Anthony Fernando; Medium

Johnson & Johnson

"I see a future in which **all medical devices would be smarter, connected to the cloud, being able to provide data to the surgeons** for them **to be able to in real-time deliver better surgical outcomes**…and you are seeing that already, through the digitalization of medtech and through robotics…" *J. Duato, CEO (Mar 2022)*

Medtronic

"…**When you can combine AI with the robotic system, it's really a force multiplier**. I get really excited about solutions that can provide information that's either not visible or knowable even to the user that **could reduce or eliminate unwarranted variability or human error, and over time maybe even automate certain decisions or tasks so that there's less for the surgeon to have to think about**…we'll see a **progression through different levels of automation** on non-clinical tasks taking place during and around the surgery…one day we won't say robotic surgery, we'll just say "surgery," and it won't seem like a big divide between the two spaces." *T. Accardi, VP of R&D for Surgical Robotics (Mar 2021)*

INTUITIVE

"I don't think we will be talking about robotics-assisted surgery as something different…it will just be the way things are done. **It will be so ubiquitous it will not be commented upon**… **it will be a rare one to not have an intelligence component to it, not the other way around**… I don't think of us as a robotics company… we are a hardware + optics + software + electronics + wetware company – **we are creating a technology-enabled ecosystem that can deliver an outcome** and several companies will begin to model that idea." *G. Guthart, CEO (Nov 2022)*

ASENSUS SURGICAL

"**…The next frontier of surgery is upon us — Performance-Guided Surgery**…we're starting to see the market mature to **focus on reducing the cognitive load on the surgeon and the physical load.**.. With digital surgery, it's leveraging the technology behind robotics but builds on that with augmented intelligence and machine learning to **amplify the intelligence surgeons can receive before, during, and after surgery**…
"**Robotics-assisted technology can support the high volume, low-cost procedures that are typically performed with ambulatory surgery centers** (ASCs)… [it] offers low operating cost… that allows hospitals to leverage existing technology investments." *A. Fernando, CEO (Apr, Jan 2022)*

Hospital & Health System Leaders on Robotic Surgery Programs

Adoption of robotics as a service line driven by cost, outcomes, interest, and tight capacity constraints

Key Themes
Increase in out-patient surgeries, especially with capacity constraints
Adoption of robotic platforms will be driven by data (*e.g.*, reduced mortality, reduced complications, improved length of stay, improved satisfaction, increased volume, and cost-effectiveness)
Higher focus on standardization of surgery to reduce unwanted variability
Management of robotic surgery as a service line to maximize ROI

SURGERY PARTNERS

"…what we think about is how do we give [physicians] the same comforts for those outpatient surgeries when they can be done in a facility that's a better value to the patient**….we see that as a big opportunity** because there are **big chunks of outpatient procedural** business that right now **are only in an inpatient setting because of a piece of technology**. And we continue to focus on ways to empower physicians to take those patients to the right setting with high-quality, great customer experience…"

J. Evans, CEO, Director (Aug 2022)

SENTARA

"While some health systems view robotic surgery as a 'tool', **many systems manage robotic surgery as a 'service line**.' They have a vision for this service line, with service line strategies, standardized processes, and policies across the entire system. At Sentara, early on, robotics was managed hospital by hospital and even surgeon by surgeon. **Today, Sentara has a service line model where the surgeons, management and clinical staff come together to look at the needs in the community and the demand models**."

"We believe the key to **our success is having the ability to repeatedly and reliably deliver high-quality outcomes** and excellent customer experiences. **To do that, you have to have standardization; unwanted variation is the enemy of quality and service excellence**. Standardization has been a core part of what we've done and how we've done it."

H. Kern, President & CEO (Feb 2022)

Dignity Health.

"At Dignity Health, **by managing robotic surgery as a service line the system's leaders can ask, "Are we doing the right cases to maximize the return on our investment?"** The service line approach has advantages in entering into value-based agreements with commercial plans…**Managing as a service line puts greater focus on metrics that matter to plans**.

We look at data extensively. We look at the length of stay, readmission rates, surgical site infections, and throughput and we've started looking at not just margin per case but margin per minute."

J. Jackson, CFO (Feb 2022)

Sources: Surgery Partners Q2 2022 Earnings Call; Becker's Hospital Review

J&J plans to add value with data and analytics before, during, and after procedures

J&J's Approach to Digitizing Peri-operative Care

Pre-operative planning	Intra-operative Care	Post-operative Monitoring & Care
Deployment of **data and analytics, augmented reality (AR), and virtual reality (VR) tools that can enhance training and procedure planning** with high-fidelity patient-specific simulation, providing surgeons with a clearer roadmap for surgery	Creation of a platform based on **intra-operative imaging and intelligent instrumentation that provides real-time surgical navigation of critical structures** to help operators carry out delicate maneuvers and avoid damage to adjacent tissues and organs	Integration of solutions such as **sensors for post-operative patient monitoring and rehabilitation;** reducing surgical variability by sharing use cases on surgical methodologies through an online network and providing the option to pair junior surgeons from any part of the world with more experienced mentors

Source: J&J MedTech

A few players are moving to become comprehensive robotics players with multiple types of platforms spanning different specialties

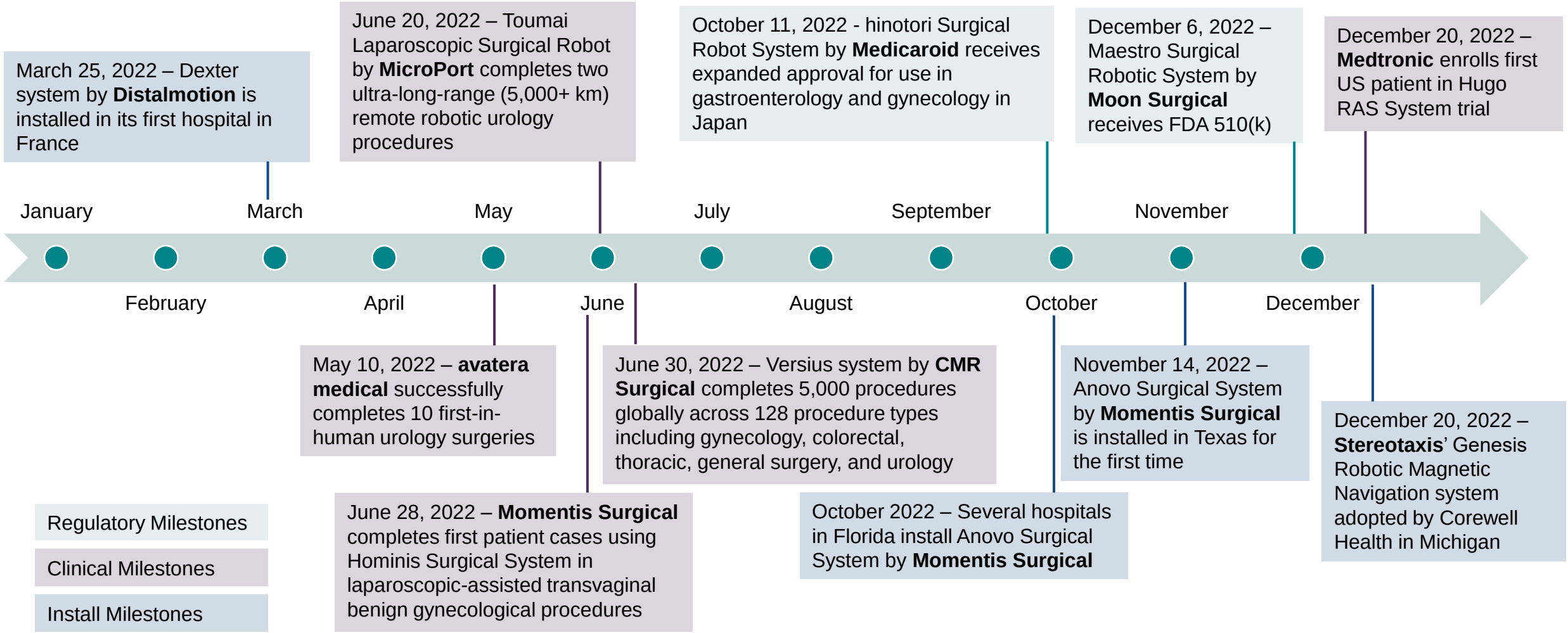
Robotic Assisted Surgery Portfolio of Selected Companies

	Surgical Platforms, MIS		Positioning/Navigation-enabled Platforms		
	Laparoscopic	Endoluminal	Hard-Tissue	Soft-Tissue	Vascular Navigation
Johnson & Johnson	**OTTAVA** Clinical Trials	**MONARCH** FDA (2018)	**VELYS** FDA (2021)	$85M Investment into Histosonics	**Impella with SmartAssist** (Acquisition of Abiomed)
MicroPort	**Toumai** NMPA (China)	Clinical Trials	**SkyWalker** NMPA (China) FDA (2022)		Clinical Trials, Partnership with Robocath
佗道医疗 TUODAO MEDICAL	Pre-clinical, Prototype stage		Pre-clinical, Prototype stage	Pre-clinical, Prototype stage	

There may be a rapid proliferation of Chinese companies within the RAS space in the coming years. China's robot industry is rapidly growing at a CAGR of 15%, with a robot density that is twice the global average. In its 14th robot industry 5-year-plan, China aims to establish an innovation system, promote university-industry partnerships to develop new technologies, increase the supply of high-end robotics products including those in the medical industry, and provide planning and financial resources to projects involved in the development of robotic technologies.

Source: FSI Analysis, 14th Robot Industry Five-Year Plan (China)

Numerous robotics companies achieved milestones in 2022, culminating in Medtronic enrolling first US patient for Hugo trial



Sources: Company press releases; Note: Selected events, timeline is not exhaustive

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110 unique companies offer 128 platforms

- 96 companies have one platform
- 10 companies have two platforms
- 4 companies have three platforms

Notes: Number in parenthesis indicates the number of platforms in the space.

[1] Multiple platforms in the same sub-category but different specialty are counted once; however, platforms in different sub-categories are counted separately (*e.g.*, Corin Group has two separate platforms addressing bone cutting (hip replacement and knee replacement) which are counted once. Curexo has CUVIS-Joint 150 for bone cutting and CUVIS-Spine for screw placement which are counted separately). [2] Does not include Cornerstone robotics which is very stealth and has not been further categorized; [3]Globus Medical has one platform for Screw Placement and Needle / Probe Positioning

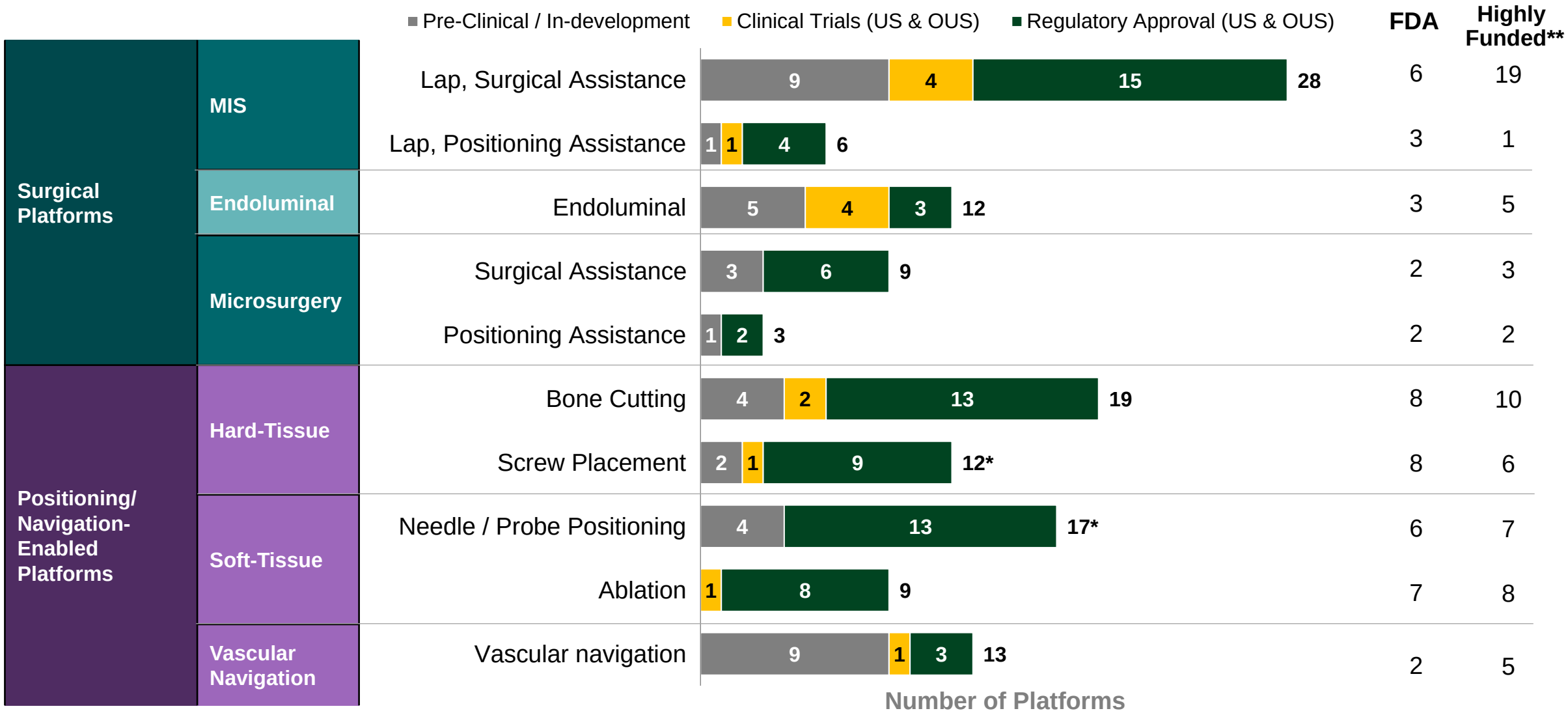
Surgical Platform: Goals and Applications

Category	Sub-category	Goal	Applications
MIS	**Laparoscopy, Surgical Assistance**	Provides improved dexterity, control, and visualization for minimally invasive procedures	General surgery, OB/GYN, urology, cardiothoracic, ENT
	Laparoscopy, Positioning Assistance	Assists by holding instrument and/or laparoscope to provide improved stability during surgical procedures and/or provide traction. Aim to remove the need for a surgical assistant	General surgery, OB/GYN, urology, cardiothoracic, ENT
	Endoluminal	Endoluminal Laparoscopy: Aims to offer triangulation with improved dexterity within a natural cavity Bronchoscopy: Aids with lung biopsy to improve the diagnostic yield; ultimately aim to deliver treatment Ureteroscopy: Assists with kidney stone removal	General surgery, OB/GYN, Urology, lung
Microsurgery	**Surgical Assistance**	Provides high level of precision along with tremor filtration, motion scaling, and advanced visualization	Ophthalmology, cochlear implantation, open surgery requiring a high-level of precision (e.g., lymphatic surgery, free flap surgery, hand surgery), hair transplant
	Positioning Assistance	Provides improved stability and enables two-handed procedures	Neurosurgery, ophthalmoscopy

Positioning / Navigation-enabled Platforms: Goal and Applications

Category	Sub-category	Goal	Applications
Hard-tissue	**Bone Cutting**	Helps with bone removal (cutting, polishing, reaming, *etc*.) for implants with the aid of planning software and navigation technology	Knee, hip, dental
	Screw Placement	Focuses on the insertion of pedicle screws with improved accuracy	Spine, pelvis, multispecialty (spine, pelvis, hip, shoulder, ankle, hand)
Soft Tissue	**Needle / Probe Positioning**	Assists with positioning of needle, probe, and / or electrode for diagnosis or treatment; planning and navigation used to guide the positioning	Neurosurgery, plastics, percutaneous procedures, oncology (lung, prostate)
	Ablation	Provides minimally invasive or non-invasive delivery of treatment (*e.g*., radiotherapy, cryoablation) guided by planning and navigation	Oncology (liver, lung, kidney, bone, prostate, and pancreas), prostate, neurosurgery, multispecialty (brain, urology, GYN, ortho, oncology, general, and/or plastics)
Vascular Navigation	**Vascular Navigation**	Aims to reduce radiation exposure for the surgeons and patients, improve control, and allow remote site control	Cardiovascular applications (stent placement, catheter guidance, mitral valve repair, electrophysiology, etc.), neurology (self-cleaning shunt), neurovascular, interventional radiology, peripheral artery

59% of platforms have regulatory approval, 11% are undergoing clinical trials, and 30% are pre-clinical/in-development



*Globus Medical has the same platform for screw placement and needle / probe positioning but counted under both categories; **Funding >$50M or public companies (US or OUS)

FDA Approved/Cleared Platforms from Major Players with Revenue >$3B *(1 of 2)*

	Product(s)	Description	Category
INTUITIVE SURGICAL®	da Vinci (Xi, X)	• Provides multi-quadrant access for performing robotic assisted laparoscopic surgery • Combines surgeon console, a vision cart, and patient cart with 3-4 robotic arms with wristed instruments for enhanced precision • Includes 3D HD vision system via endoscope	Surgical Platform, MIS, Laparoscopy, Surgical Assistance
	da Vinci Sp	• Provides single port access through a 25mm cannula • Designed to aid in robotic visualization, precision, and dexterity with triangulation • Consists of a surgeon console, a patient cart, and a vision cart	
	Ion	• Robotic assisted platform for minimally invasive biopsy in the lung • Relies on fiber optic shape sensing technology for navigation • Smaller diameter (3.5mm for Ion *vs.* 4.2mm for Monarch) allows access to smaller distal airways	Surgical Platform, MIS, Endoluminal
J&J	Monarch	• Uses flexible robotics to enhance visualization and precisely target areas within the lung and kidney • Relies on electromagnetic navigation • Constant visualization allows for directional targeting of instruments	Surgical Platform, MIS, Endoluminal
ZEISS	Zeiss Kinevo 900	• Provides surgeon-controlled robotics assistance for microscopy improving stability during neurosurgical procedures	Surgical Platform, Microsurgery, Positioning Assitance
Corindus A Siemens Healthineers Company	CorPath GRX	• Robot for remote delivery and manipulation of coronary guidewires and stent/balloon devices through radial or femoral access • Improves procedural control, provides better precision, and increases radiation safety	Positioning / Navigation-enabled Platform, Vascular Navigation

Not an exhaustive list of platforms offered by major players

FDA Approved/Cleared Platforms from Major Players with Revenue >$3B (2 *of* 2)

	Product(s)	Description	Category
smith&nephew	NAVIO	• Used for total knee arthroplasty • 3D model of the anatomy of interest is created through direct surface mapping Soft-tissue kinematics are evaluated using a software • Robotic assisted hand-held system is used to cut and prepare the bone • Implants are inserted and the system allows surgeons to evaluate the joint laxity compared to the pre-operative plan	Positioning / Navigation-enabled Platform, Hard-tissue, Bone cutting
stryker	MAKO	• Patient gets CT scan of the knee and the anatomical information is incorporated into the robotic software • Soft-tissue kinematics are evaluated using a software • Robotic arm used to precisely cut the bone allowing accurate placement of the implant • Provides haptic feedback to ensure surgeon stays within specified margins	Positioning / Navigation-enabled Platform, Hard-tissue, Bone cutting
ZIMMER BIOMET Your progress. Our promise.	ROSA Knee	• Assists with bone resections and evaluating soft tissues to optimize implant positioning during the operation • Has cut-guides attached to the robotic arm to stay within margins • Rosa uses X-ray data and optical tracker to know the knee position	Positioning / Navigation-enabled Platform, Hard-tissue, Bone cutting
	ROSA One (Brain)	• Preoperative images are loaded into the software • Patient is positioned and registration is performed using optical tracking • Instruments are guided and positioned with speed and depth control	Positioning / Navigation-enabled Platform, Soft-tissue, Needle / Probe Positioning
Medtronic	Mazor X	• Used for spine surgery • Uses CT scan for planning the implant position and standing X-ray images for spinal alignment • Robotic arm is used to guide tools according to the surgical plan with the help of a 3D camera and CT-fluoro registration	Positioning / Navigation-enabled Platform, Hard-tissue, Screw Placement

Not an exhaustive list of platforms offered by major players

58 total Surgical Platforms, 30 with regulatory approval; Laparoscopy a crowded segment with 34 platforms

Stage of Product	Laparoscopy	Endoluminal	Microsurgery
FDA clearance / approval	Asensus Surgical; Human Xtensions; Dex Surgical; Medrobotics; Momentis Surgical; Intuitive Surgical; freehand; Moon Surgical; AKTORmed Robotic Surgery	EndoTools Therapeutics; Intuitive Surgical; J&J	Venus Concept; Zeiss; synaptive; iotamotion
OUS regulatory approval	Medtronic; CMR Surgical; Distalmotion; Riverfield; meere company; Medicaroid; Edge Medical 精锋医疗; SS Innovations; MicroPort; avatera		microsure; Cascination; Zeiss; MMI Microinstruments
US clinical trials	Virtual Incision	Endoquest Robotics	
OUS clinical trials	Levita Magnetics; Great Robotics; 术锐 Shurui; Wego Ortho 威高骨科	MicroPort; Robo; EndoMaster	
In-development	Titan Medical; Riverfield; USMI US Medical Innovations; J&J; Asahi Surgical Robotics; 佗道医疗 Tuodao Medical; Panther Healthcare 派尔特医疗; Borns; rob surgical; Vicarious Surgical	Virtuoso Surgical; Noah Medical; Caranx Medical; rm tech 元化; Agilis Robotics	Acusurgical; Forsight Robotics; Riverfield; Galen Robotics

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

34 Laparoscopy MIS platforms, 20 with regulatory approval; 16 companies highly funded or public in the US

Stage of Product	Surgical Assistance: Multi-port	Surgical Assistance: Single-port	Positioning Assistance
FDA clearance / approval	ASENSUS SURGICAL; HUMAN XTENSIONS™; Dex Surgical; INTUITIVE SURGICAL	MOMENTIS SURGICAL; Medrobotics	freehand; AKTORmed ROBOTIC SURGERY; MOON SURGICAL
OUS regulatory approval	meerecompany; CMR SURGICAL; Distalmotion; SS INNOVATIONS; Medicaroid; avatera; Medtronic; MicroPort	EDGE MEDICAL 精锋医疗	RIVERFIELD
US clinical trials		VIRTUALINCISION	
OUS clinical trials	GREAT ROBOTICS; WEGO ORTHO 威高骨科	术锐 SHURUI	Levita MAGNETICS
In-development	佗道医疗 TUODAO MEDICAL; USMI US Medical Innovations; RIVERFIELD; J&J; Panther Healthcare 派尔特医疗; BORNS; rob surgical	TITAN MEDICAL; VICARIOUS SURGICAL	ASAHI SURGICAL ROBOTICS

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

Many lap platforms received recent approval and compete with Intuitive on operational & economical value proposition

Overall	**34**
Founded since 2017	**4**
FDA clearance / approval	**9**
OUS regulatory approval	**10**
US clinical trials	**1**
OUS clinical trials	**4**
Pre-clinical / In-development	**10**
$5-24M in funding	**6**
$25-49M in funding	**5**
$50-100M in funding	**2**
>$100M in funding	**6**
Public companies	**12**

Note: 7 companies with unknown funding

	Surgical Assistance	Positioning Assistance
Major Players	Intuitive Surgical (da Vinci)	None
New players growing the market vs. taking shares for major players	• Many single port and multi-port laparoscopic platforms have obtained recent regulatory approval and hit the market • New platforms help convert more open and conventional laparoscopic procedures to robotics, but may take share with smaller foot-print and cost-effective robots	• Could take share from robotic players by encouraging more conventional laparoscopy • Some experienced surgeons are hesitant about the benefits of robotic surgery, while others lack access • Smaller foot-print assistants that are lower capital cost may be appealing to ASCs and small-medium hospitals
Incremental changes vs. revolutionary compared to major players	• New platforms offer incremental improvements to existing platforms with low level of automation compared to existing technology; compete on operational and economical value prop • Few platforms starting to leverage data	• New players aim to offer tissue traction along with camera holding, providing a significant clinical and operational benefit • Players aims to reduce the number of incisions for laparoscopic surgery
Examples of automation	• Provide instrument guidance on based on best-practices	• None
Opportunities for early investment	• Crowded space with over 16 robots that have regulatory approval • Early-stage platforms plan to provide incremental benefits over existing technology with few that aim to leverage data and analytics to drive value	• 2 potential platforms for early-stage investment with a unique value proposition • 4 platforms already have regulatory approval. The space is not very technical

Recent laparoscopic platforms offer incremental hardware benefits over major players; potential to leverage data

Overall	**28**
Founded since 2017	**3**
FDA clearance / approval*	**6**
OUS regulatory approval	**9**
US clinical trials	**1**
OUS clinical trials	**3**
Pre-clinical / In-development	**9**
$5-24M in funding	**5**
$25-49M in funding	**2**
$50-100M in funding	**2**
>$100M in funding	**6**
Public companies	**11**

Note: 2 companies with unknown funding

Goal

Provide improved dexterity, control, and visualization for minimally invasive procedures.

Differentiators (Multiport)

Commercial

- Ability to connect to hospital information system
- Modular arms for easy positioning & docking
- Instrument type: flexible, smaller (3mm)
- Force feedback: haptic, force display
- Sterile surgeon can switch between laparoscopic (*e.g.,* stapling) and robotic surgery (*e.g.,* suturing)
- 2 platforms with electromechanical laparoscopic instruments provide a low-cost alternative allowing surgeons to perform laparoscopic surgery at the bedside with wristed instruments

Pipeline

- Data analytics (e.g., personalized training, margin detection, hazard alerts, no-fly zones)
- Imaging integrates with CT imaging
- Designed specifically for spinal endoscopic surgery with image guidance

Differentiators (Single Port)

Commercial

- 6 platforms offer flexible instruments, and 2 offer rigid instruments
- Platforms are further differentiated in a variety of ways including an additional instrument arm (2 vs. 3 arms), extra DOFs, and indication for use

Pipeline

- One platform is designed specifically for bowel resections

Applications:

- General surgery
- OB/GYN procedures
- Cardiothoracic
- Urology
- ENT

Pre-clinical platforms assist by providing traction with camera holding and reduce the number of incisions

Overall	**6**
Founded since 2017	**1**
FDA clearance / approval	**3**
OUS regulatory approval	**1**
US clinical trials	**0**
OUS clinical trials	**1**
Pre-clinical / In-development	**1**
$5-24M in funding	**1**
$25-49M in funding	**3**
$50-100M in funding	**0**
>$100M in funding	**0**
Public companies	**1**

Note: 5 companies with unknown funding

Goal

Assists by holding instrument and/or laparoscope to provide improved stability during surgical procedures and/or provide traction. Aim to remove the need for a surgical assistant

Differentiators

Commercial

- Platforms can be controlled in a variety of ways including voice control, foot pedal, and/or headsets

Pipeline

- Assist with laparoscope holding and manipulation along with retraction
- Reduce the number of incisions required to perform laparoscopic surgery

12 Endoluminal platforms and 3 have approval; no major players in the endoluminal laparoscopy space

Stage of Product	Bronchoscopy	Ureteroscopy	Laparoscopy: General	Laparoscopy: Urology & GYN
FDA clearance / approval	Intuitive Surgical; J&J		EndoTools Therapeutics	
US clinical trials			EndoQuest Robotics	
OUS clinical trials	MicroPort		ROBO; EndoMaster	
In-development	Noah Medical		Caranx Medical; rm Tech; Agilis Robotics	Virtuoso Surgical

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

Bronchoscopy has large strategics including Intuitive and J&J; only 1 endoluminal laparoscopy platform has regulatory approval

Overall	**12**
Founded since 2017	**4**
FDA clearance / approval	**3**
OUS regulatory approval	**0**
US clinical trials	**1**
OUS clinical trials	**3**
Pre-clinical / In-development	**5**
$5-24M in funding	**4**
$25-49M in funding	**1**
$50-100M in funding	**1**
>$100M in funding	**1**
Public companies	**3**

Note: 2 companies with unknown funding

	Bronchoscopy/Ureteroscopy	Endoluminal Laparoscopy
Major Players	Intuitive Surgical (Ion), J&J (Monarch)	None
New players growing the market vs. taking shares for major players	• Major players have not been in the lung biopsy market for a long time • New technology with better diagnostic yield could gain market share; however major players are strengthening their position by adding therapeutic solutions and expanding indications (e.g., J&J got clearance for urology in May 2022. Plans to complete first-in-human study) • New players could expand the overall market as lung cancer screening is not utilized to its full potential	• Success of players in the endoluminal space could impact major players offering laparoscopic platforms, especially single-port, as endoluminal robots provide scarless option which may be more appealing to patients • Cover endoscopic procedures to robotics • Offer smaller foot-print with lower capital investment which may be appealing to small-medium hospitals
Incremental changes vs. revolutionary compared to major players	• Platforms aim to improve outcomes through incremental innovation (respiratory compensation, tool-in-lesion tomography) to the existing platforms	• Endoluminal laparoscopy platforms differentiate from each other through minor technical differences (e.g., flexile instruments, extra degree of freedom, use of nitinol for improved strength)
Opportunities for early investment	• Limited opportunities as those without regulatory approval have $100M+ in funding	• Only 1 platform has regulatory approval with 7 platforms undergoing clinical trials or in-development • No major players in the space, but would compete with laparoscopic platforms such as da Vinci single-port

Endoluminal platforms without regulatory approval provide incremental benefits over systems on market

Overall	**12**
Founded since 2017	**4**
FDA clearance / approval	**3**
OUS regulatory approval	**0**
US clinical trials	**1**
OUS clinical trials	**3**
Pre-clinical / In-development	**5**
$5-24M in funding	**4**
$25-49M in funding	**1**
$50-100M in funding	**1**
>$100M in funding	**1**
Public companies	**3**

Note: 2 companies with unknown funding

Goal

Endoluminal Laparoscopy: Aim to offer triangulation with improved dexterity within a natural cavity
Bronchoscopy: Aid with lung biopsy to improve the diagnostic yield; ultimately aim to deliver treatment
Ureteroscopy: Assists with kidney stone removal

Differentiators (bronchoscopy / ureteroscopy)

Commercial

- Size of instruments
- Navigation technology used

Pipeline

- Ability to compensate for breathing
- Single-use bronchoscope
- Tool-in-lesion tomography (TiLT) to reduce CT-to-body divergence

Applications

- Lung
- Urology

Differentiators (endoluminal laparoscopy)

Commercial

- Independent control of the camera position

Pipeline

- Point of entry (oral, transrectal, transvaginal)
- Leveraging augmented reality
- Use of flexible instruments

Applications

- General surgery
- OB/GYN procedures
- Urology

12 Microsurgery platforms, 8 with regulatory approvals; 4 companies are well-funded

Stage of Product	Surgical Assistance				Positioning Assitance
	Multispecialty	Otology	Ophthalmology	Hair Transplant	
FDA clearance / approval		iotamotion Hearing, advanced.		VenusConcept	synaptive, ZEISS
OUS regulatory approval	microsure, MMI Microinstruments	CASCINATION	ZEISS		
In-development	GALEN ROBOTICS		FORSIGHT ROBOTICS., ACUSURGICAL		RIVERFIELD

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

Surgical assistance space is exciting with low competition, especially in open microsurgery and ophthalmology

Overall	**12**
Founded since 2017	**2**
FDA clearance / approval	**4**
OUS regulatory approval	**4**
US clinical trials	**0**
OUS clinical trials	**0**
Pre-clinical / In-development	**4**
$5-24M in funding	**3**
$25-49M in funding	**2**
$50-100M in funding	**1**
>$100M in funding	**2**
Public companies	**2***

	Surgical Assistance	Positioning Assistance
Major Players	None	Carl Zeiss
New players growing the market vs. taking shares for major players	• Robots are addressing various clinical indications likely growing the overall market	• Limited impact as only one player directly competes with Carl Zeiss • Other player is targeting a different application
Incremental changes vs. revolutionary compared to major players	• Revolutionary as benefits of robots are brought to new applications	• Niche field with only 3 players
Examples of automation	• Leveraging AI and ML to monitor instrument movements and compare against experts with ultimate goal of providing guidance for surgery • Able to memorize instrument paths for consistent, repeatable movements	• Able to automatically track instruments as the microscope moves to follow the instruments • Able to store identified regions of concern and move to position as needed
Opportunities for early investment	• Good potential to invest as early-stage platforms are addressing new markets with limited competition • No platforms for ophthalmology and open surgery in the US • Platforms plan to offer unique business models and leverage data	• Very limited as only 1 platform is pre-clinical, while other 2 have FDA clearance

Note: 1 company with unknown funding; *Carl Zeiss offers a platform for surgical and positioning assistance. Only counted once

Microsurgery platforms are bringing the benefits of robotics surgery to various applications

Overall	**9**
Founded since 2017	**2**
FDA clearance / approval	**2**
OUS regulatory approval	**4**
US clinical trials	**0**
OUS clinical trials	**0**
Pre-clinical / In-development	**3**
$5-24M in funding	**3**
$25-49M in funding	**1**
$50-100M in funding	**1**
>$100M in funding	**1**
Public companies	**1**

Note: 2 companies with unknown funding

Goal

Provide high level of precision along with tremor filtration, motion scaling, and advanced visualization

Differentiators

Commercial

- Size of the instruments
- Offers wristed micro-instruments
- Precision achieved (accuracy of 20 microns)
- Degrees of freedom offered

Pipeline

- Data analytics integrated to improve surgical efficiency
- Support features to memorize instrument paths (*e.g.*, biopsy needle entry) to reliably repeat movement
- Leveraging AI and ML to monitor instrument movements and compare against experts

Applications

- Ophthalmology
- Cochlear implantation
- Open surgery requiring a high-level of precision (*e.g.*, lymphatic surgery, free flap surgery, hand surgery)
- Hair transplant

Although relative niche space, microsurgery positioning assistance platforms provide high level of automation

Overall	**3**
Founded since 2017	**0**
FDA clearance / approval	**2**
OUS regulatory approval	**0**
US clinical trials	**0**
OUS clinical trials	**0**
Pre-clinical / In-development	**1**
$5-24M in funding	**0**
$25-49M in funding	**1**
$50-100M in funding	**0**
>$100M in funding	**1**
Public companies	**1**

Goal

Provides improved stability and enables two-handed procedures

Differentiators

Commercial

- Able to focus and move around a structure to visualize the targeted anatomy
- Able to store identified regions of concern and recall as needed
- Tracked instruments provide automatic control of camera position and focus

Applications

- Neurosurgery
- Ophthalmoscopy

70 total Positioning / Navigation-enabled Platforms, 45 with approval; Vascular Navigation ripe with development pipeline

Stage of Product	Hard tissue	Soft tissue	Vascular Navigation
FDA clearance / approval	NUVASIVE, Medtronic, THINK SURGICAL, MicroPort, POINT, J&J, ecential robotics, Accelus, neocis, BRAINLAB, ZIMMER BIOMET, GLOBUS MEDICAL, stryker, Corin, CUREXO, smith&nephew	ZIMMER BIOMET, ACCURAY, MONTERIS MEDICAL, QUANTUM surgical, edap tms, CASCINATION, ACOUSTIC MEDSYSTEMS, PROCEPT BioRobotics, XACT Robotics, biobot, Dominion Aesthetic Technologies, GLOBUS MEDICAL, INSIGHTEC, RENISHAW	STEREOTAXIS, Corindus
OUS regulatory approval	长木谷, CUREXO, TINAVI 天智航, rm TECH 元化, Remebot, AOT Advanced Osteotomy Tools	NDR Medical Technology, THERACLION, BRAIN NAVI, Remebot, SS INNOVATIONS, Perfint, Soteria Medical	Robocath
US clinical trials		HISTOSONICS	
OUS clinical trials	LONGWELL, Jianjia Robots, ROSSUM ROBOT		奥朋医疗
In-development	caira, amplitude SURGICAL, 佗道医疗 TUODAO MEDICAL, monogram, MASMEC BIOMED, CYBERDONTICS	neuro42, CLEARPOINT NEURO, ZETA SURGICAL, 佗道医疗 TUODAO MEDICAL	RainMed, Catheter Precision, medipixel, Artedrone, EndoWays, GREAT ROBOTICS, microbot medical, MORAY MEDICAL, Xcath

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

32 Hard-tissue platforms, 22 with regulatory approval; 14 platforms highly funded or public in the US

Stage of Product	Bone Cutting			Screw Placement		
	Knee	Hip	Dental	Spine	Pelvis	Multi-specialty
FDA Clearance / Approval	THINK SURGICAL, MicroPort, smith&nephew	J&J, Corin, stryker, ZIMMER BIOMET	neocis	Medtronic, Accelus, ecential robotics, GLOBUS MEDICAL, BRAINLAB, NUVASIVE, CUREXO, POINT		
OUS regulatory approval	rm TECH 元化, 长木谷, AOT Advanced Osteotomy Tools, CUREXO		Remebot			TINAVI 天智航
OUS clinical trials	Jianjia Robots, LONGWELL				ROSSUM ROBOT	
In-development	caira, monogram, amplitude SURGICAL		CYBERDONTICS	佗道医疗 TUODAO MEDICAL, MASMEC BIOMED		

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

Note: Rafina Innovations not included but provides passive support during orthopedic procedures

Bone Cutting and Screw Placement has 4 major players; pre-clinical platforms in Bone Cutting are more innovative

Overall	32*
Founded since 2017	8
FDA clearance / approval	16
OUS regulatory approval	6
US clinical trials	0
OUS clinical trials	3
Pre-clinical / In-development	7
$5-24M in funding	8
$25-49M in funding	5
$50-100M in funding	1
>$100M in funding	6
Public companies	9**

	Bone Cutting	Screw Placement
Major Players	Smith & Nephew, Stryker, Zimmer Biomet, J&J	Medtronic, Globus Medical, Brainlab, NuVasive
New players growing the market vs. taking shares for major players	• Four major players in the growing knee and hip replacement market with aging population • Newer players aim to increase automation, provide personalized solutions, reduce cost, and/or significantly lower set-up time may take share from major players especially as orthopedic surgery moves to outpatient setting • New applications such as dental increasing the overall market size	• Four major players with regulatory approval in this space for pedicle screw placement in spine surgery • Newer players that aim to increase automation and provide data integration (e.g., integration with neuromonitoring) may take share from major players • Platforms expanding to other applications increasing the overall market size
Incremental changes vs. revolutionary compared to major players	• Most platforms are improving technology with incremental changes, while few are planning a major shift with personalized implants or reducing set-up time by 5x • Field of dental robotics is emerging and plans to reduce the number of visits to the dentist	• Although changes are incremental, platforms aim to simplify planning or positioning through automation • Platforms also aim to provide a single platform for multiple applications
Examples of automation	• Autonomous bone cutting • Using AI to shorten pre-operative planning	• Automated image registration • Automated drilling and screw placement
Opportunities for early investment	• 13 of 19 platforms have regulatory approval including 4 major players • Potential to invest in pre-clinical platforms as they plan to offer significant clinical, economical, and/or operational benefit over existing technology • One platform also bringing robotics to root canal procedure	• 9 of 12 platforms have regulatory approval • Platforms without regulatory approval are not highly innovative

Note: 2 companies with unknown funding; *Globus Medical uses the same platform for soft-tissue and hard-tissue. Rafina Innovation provides passive leg support; **Curexo has robots for screw placement and bone cutting. Only counted once

Bone Cutting platforms aim to increase automation during pre-operative planning and cutting phase

Overall	**19**
Founded since 2017	**6**
FDA clearance / approval	**8**
OUS regulatory approval	**5**
US clinical trials	**0**
OUS clinical trials	**2**
Pre-clinical / In-development	**4**
$5-24M in funding	**6**
$25-49M in funding	**3**
$50-100M in funding	**1**
>$100M in funding	**3**
Public companies	**6**

Goal

Helps with bone removal (cutting, polishing, reaming, *etc.*) for implants with the aid of planning software and navigation technology

Differentiators

Commercial

- Autonomous ("hand-free") cutting versus surgeon guided cutting
- Type of technology/imaging used for procedural planning (pre-operative CT scans, intraoperative X-ray, or direct surface mapping – preop imaging not required)
- Use of lasers for bone cutting
- Able to track bone movement during cutting at a high frequency to automatically reposition the saw
- Hip: works on the acetabular side and the femoral side

Pipeline

- Use of AI to shorten time for pre-operative planning
- Personalized implants
- Claim to reduce set-up time and lower cost by using radar imaging
- Dental: aim to reduce the number of visits to the physician through pre-planning

Applications

- Knee
- Hip
- Dental

Screw placement platforms without regulatory approval are not highly differentiated compared to marketed products

Overall	**12***
Founded since 2017	**2**
FDA clearance / approval	**8**
OUS regulatory approval	**1**
US clinical trials	**0**
OUS clinical trials	**1**
Pre-clinical / In-development	**2**
$5-24M in funding	**2**
$25-49M in funding	**2**
$50-100M in funding	**0**
>$100M in funding	**3**
Public companies	**3**

Goal

Focused on the insertion of pedicle screws with improved accuracy

Differentiators

Commercial

- Force sensing for screw insertion
- Integrates with neuromonitoring
- Does not require pre-operative imaging
- Universal end-effector that enables multiple procedures

Pipeline

- Automatic image registration

Applications

- Spine
- Pelvis
- Multispecialty (spine, pelvis, hip, shoulder, ankle, hand)

Note: 2 companies with unknown funding; *Globus Medical uses the same platform for soft-tissue and hard-tissue

26 Soft-tissue platforms, 21 with regulatory approval; 11 platforms highly funded or public in the US

Stage of Product	Needle / Probe Positioning				Ablation			
	Neuro	Oncology	Percut.	Plastics	Neuro	Oncology	Prostate	Multi-specialty
FDA clearance / approval	ZIMMER BIOMET, GLOBUS MEDICAL, RENISHAW	biobot, ACOUSTIC MEDSYSTEMS	XACT Robotics	Dominion Aesthetic Technologies, Inc.	MONTERIS MEDICAL	QUANTUM surgical, CASCINATION, ACCURAY	PROCEPT BioRobotics, edap tms	INSIGHTEC
OUS regulatory approval	BRAIN NAVI, Remebot	Perfint, Soteria Medical	NDR Medical Technology	SS INNOVATIONS				THERACLION
US clinical trials						HISTOSONICS		
In-development	CLEARPOINT NEURO, neuro42, ZETA SURGICAL		佗道医疗 TUODAO MEDICAL					

>$100M in funding or OUS public company with >$50M in revenue

Publically traded in the US

Needle / Probe Positioning platforms has few innovative players; only 1 Ablation platform without regulatory approval

Overall	**26***
Founded since 2017	**2**
FDA clearance / approval	**14**
OUS regulatory approval	**7**
US clinical trials	**1**
OUS clinical trials	**0**
Pre-clinical / In-development	**4**
$5-24M in funding	**3**
$25-49M in funding	**3**
$50-100M in funding	**3**
>$100M in funding	**4**
Public companies	**7**

	Needle / Probe Positioing	Ablation
Major Players	Zimmer Biomet, Globus Medical	None
New players growing the market vs. taking shares for major players	• Smaller platforms are going after different indications compared to the major players expanding the overall market • Few platforms aim to address limitations of existing platforms through increased automation using AI and ML. If these platforms get regulatory approval, they could potentially take share from major players	• Robotics advances non-invasive care • Platforms offering non-invasive surgery could serve as a great alternative to invasive surgery for many patients and take share from robotic players in other segments
Incremental changes vs. revolutionary compared to major players	• Although changes are incremental, platforms aim to simplify planning or positioning through automation	• Highly innovative field with many unique types of therapy (e.g., histotripsy, laser thermometry, irreversible electroporation)
Examples of automation	• Marker-less registration with computer vision • Hands-free instrument insertion	• With pre-planning input from surgeons, platforms capable of delivering automated treatment
Opportunities for early investment	• Four early-stage platforms, two are highly innovative. These platforms competing against Zimmer Biomet and Globus Medical	• Limited opportunities as 8 of 9 platforms have regulatory approval. Histosonics is undergoing clinical trial, although highly revolutionary, has funding over $200M

Note: 5 companies with unknown funding; *Globus Medical uses the same platform for soft-tissue and hard-tissue

Needle / Probe Positioning platforms aim to increase automation during the planning and positioning phase

Overall	**17***
Founded since 2017	**2**
FDA clearance / approval	**6**
OUS regulatory approval	**7**
US clinical trials	**0**
OUS clinical trials	**0**
Pre-clinical / In-development	**4**
$5-24M in funding	**3**
$25-49M in funding	**3**
$50-100M in funding	**2**
>$100M in funding	**1**
Public companies	**4**

Goal

Assist with positioning of needle, probe, and / or electrode for diagnosis or treatment; planning and navigation used to guide the positioning

Differentiators

Commercial

- Usage of multiple imaging modalities for planning and navigation (CT, MRI, ultrasound, MRI-ultrasound, real-time MRI with MRI, fluoroscopy)
- Uses Surface Mapping Auto-registration Technology (SMART) to avoid the need for intraoperative imaging
- Automatic fusion and segmentation of images from multiple modalities
- Ability to sense forces
- Use of AI for pre-operative planning
- Hands-free instrument insertion

Pipeline

- Marker less image registration using computer vision
- Combines robotics with *portable* MRI to improve access to care

Applications

- Neurosurgery (brain)
- Plastics
- Percutaneous Procedures
- Oncology (lung, prostate)

Note: 4 companies with unknown funding; *Globus Medical uses the same platform for soft-tissue and hard-tissue

Ablation platforms differentiated by the type of treatment delivered

Overall	**9**
Founded since 2017	**0**
FDA clearance / approval	**7**
OUS regulatory approval	**1**
US clinical trials	**1**
OUS clinical trials	**0**
Pre-clinical / In-development	**0**
$5-24M in funding	**0**
$25-49M in funding	**0**
$50-100M in funding	**1**
>$100M in funding	**3**
Public companies	**4**

Note: 1 company with unknown funding

Goal

Minimally invasive or non-invasive delivery of treatment (*e.g.,* radiotherapy, cryoablation) guided by planning and navigation

Differentiators

- Type of treatment delivered (radiotherapy, cryoablation, thermotherapy, ecotherapy, histotripsy, aquablation, *etc.*)
- Type of imaging to guide and/or monitor treatment

Applications

- Oncology (liver, lung, kidney, bone, prostate and/or pancreas)
- Multispecialty (brain, urology, gyn, ortho, oncology, general, and/or plastics)
- Prostate
- Neurosurgery (brain)

13 Vascular Navigation platforms, 3 with regulatory approval; 3 companies public in the US

Stage of Product	Cardiovascular	Neurovascular	Neurology	Interventional Radiology	Peripheral Artery
FDA Clearance / Approval	Stereotaxis, Corindus (A Siemens Healthineers Company)				
OUS regulatory approval	Robocath				
OUS clinical trials					奥朋医疗 (Define Vascular Operation)
In-development	medipixel, Catheter Precision, MORAY MEDICAL, RainMed, Artedrone, Xcath, GREAT ROBOTICS		microbot medical	EndoWays	

FDA Approved

Publically traded in the US

Vascular Navigation platforms without regulatory approval aim to bring robotics to new applications

Overall	**13**
Founded since 2017	**6**
FDA clearance / approval	**2**
OUS regulatory approval	**1**
US clinical trials	**0**
OUS clinical trials	**1**
Pre-clinical / In-development	**9**
$5-24M in funding	**3**
$25-49M in funding	**2**
$50-100M in funding	**1**
>$100M in funding	**0**
Public companies	**4**

Major Players	Siemens Healthineers (Corindus)
New players growing the market vs. taking shares for major players	• Companies are developing catheter navigation robots similar to Corindus, but one platform with FDA clearance is aimed for electrophysiology applications and the other robot on market with OUS approval does not offer significant advantages • Many players in development and attempting to bring the benefits of robotics to vascular navigation growing the overall market size
Incremental changes vs. revolutionary compared to major players	• Many new applications for catheter navigation robots along with various actuator mechanism • Companies are revolutionizing field with innovations such as disposable robots, single-hand control, and removing the need for a physician
Examples of automation	• AI for automated stent delivery
Opportunities for early investment	• High potential for early-stage investment with 9 platforms in-development phase addressing various applications • Has the highest number of robots in the pre-clinical phase

Note: 3 companies with unknown funding

Vascular navigation robots mainly differentiated by application and type of actuator mechanism

Overall	**13**
Founded since 2017	**6**
FDA clearance / approval	**2**
OUS regulatory approval	**1**
US clinical trials	**0**
OUS clinical trials	**1**
Pre-clinical / In-development	**9**
$5-24M in funding	**3**
$25-49M in funding	**2**
$50-100M in funding	**1**
>$100M in funding	**0**
Public companies	**4**

Note: 3 companies with unknown funding

Goal

Aids with minimally invasive procedures. Systems aim to reduce radiation exposure for the surgeons and patients, improve control, and allow remote site control

Differentiators

Commercial

- Providing single hand control reducing the need for another physician
- Image guidance based on multiple modalities
- Able to offer diagnosis and treatment
- Open platform that is compatible with various products on the market

Pipeline

- Actuator mechanism (microfluidic, magnetic, self-propelling, etc.)
- Using augmented reality and advanced 3D visualization
- Fully-disposable robots
- Using AI for automated stent delivery

Applications

- Cardiovascular applications (stent placement, catheter guidance, mitral valve repair, electrophysiology, etc.)
- Neurology (self-cleaning shunt)
- Neurovascular
- Interventional radiology
- Peripheral artery

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