WHITE PAPER

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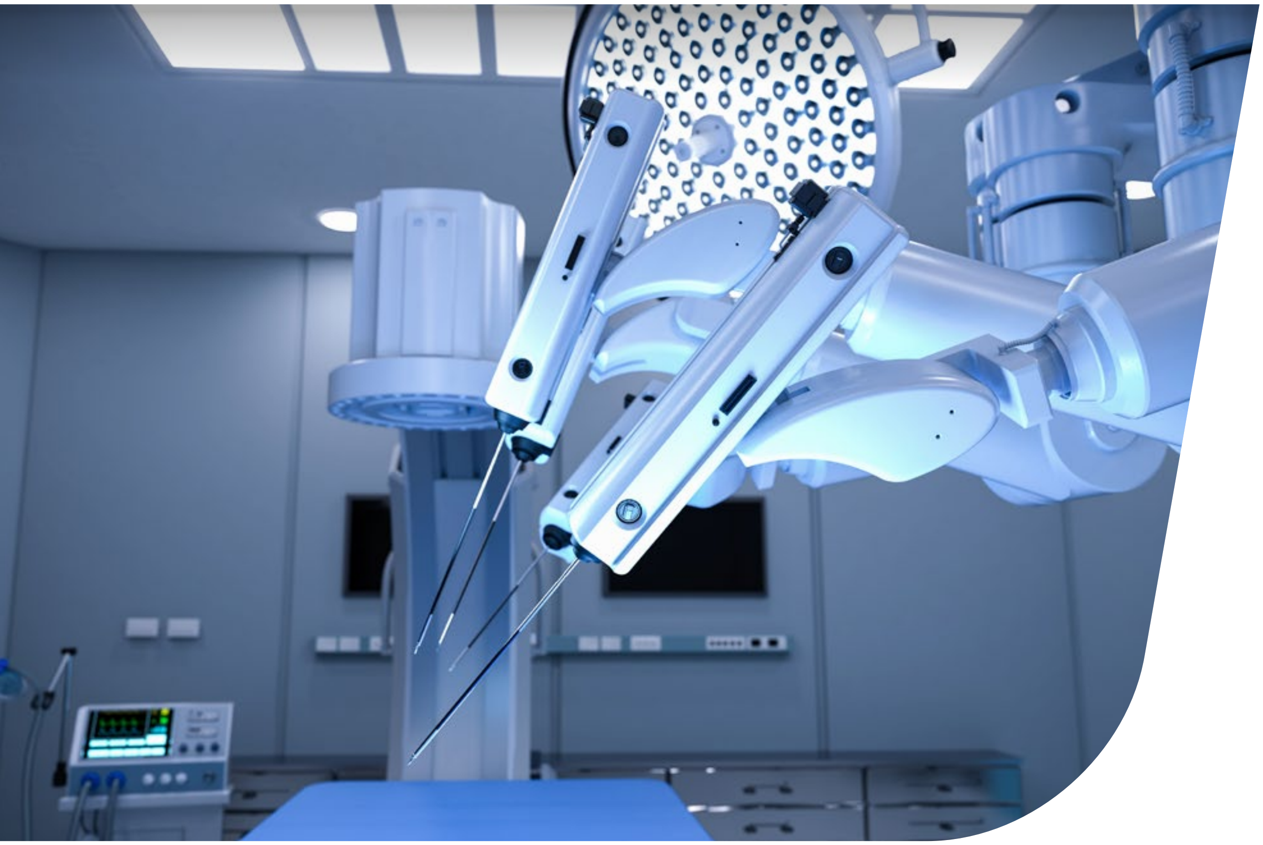
Why Motion Design Will Define the Future of Surgical Robotics



RegalRexnord™

Surgical robotics has moved well beyond its early days as a specialized technology reserved for a handful of elite operating rooms. It's now expanding rapidly across healthcare systems, taking on both established procedures and entirely new applications. As these systems scale beyond flagship hospitals and into everyday clinical environments, expectations are rising sharply – not only for capability, but for efficiency, and long-term reliability.

Minimally invasive techniques are becoming the standard of care. Artificial intelligence is increasingly shaping how procedures are planned and executed. At the same time, emerging platforms are smaller, more specialized, and accessible to a broader range of hospitals.

Together, these trends are converging on a single pressure point: motion. As surgical robotics becomes more distributed, intelligent, and cost-sensitive, motion design becomes a defining factor in whether a system can scale safely and sustainably.

A Growing Field with Growing Expectations

Recent reviews of AI-assisted robotic surgical outcomes show meaningful reductions in operative time and intraoperative complications compared to manual methods, alongside faster patient recovery[1]. Adoption has followed suit. In the UK alone, the number of robotic surgeries increased by more than 1,200% between 2019 and 2025[2], and the global surgical robotics market is projected to more than triple by the mid-2030s[3].

As utilization increases, however, the tolerance for mechanical inconsistency disappears. Variance that was once manageable – thermal drift, feedback noise, torque ripple – becomes a systemic risk when platforms are deployed at scale, across sites, surgeons, and duty cycles.

As robotic systems expand across applications and clinical settings, motion performance becomes a defining system constraint.

Simultaneously, the nature of robotic systems themselves is changing. Where the field was once dominated by a few large, general-purpose platforms, it is now characterized by fragmented, procedure-specific systems with highly variable motion requirements. Orthopedics, spine, and laparoscopic surgery are now joined by miniaturized robotic systems for bronchoscopy, urology, and cardiovascular interventions.

For OEMs, this creates a more complex design landscape. Each new system brings its own constraints around size, precision, sterility, responsiveness, and integration. Across all of them, motion remains the common denominator – and often the hardest variable to reconcile.

Minimally Invasive Surgery is Reshaping the Engineering Brief

The clinical benefits of minimally invasive surgery are well established: reduced trauma, shorter hospital stays, and improved outcomes. From an engineering perspective, however, these benefits come with a significantly tighter design envelope.

Smaller access points mean smaller instruments. Smaller instruments leave less room for motors, gearing, and feedback systems – without any reduction in the performance those components are expected to deliver. In practice, motor diameters can shrink to just a few millimeters, while system requirements demand high-speed, high-torque density, and precision control.

Clinical advances in minimally invasive surgery translate directly into tighter mechanical and thermal design envelopes for robotic surgical systems.

[1] https://pubmed.ncbi.nlm.nih.gov/40540146/

[2] https://www.nice.org.uk/news/articles/cutting-edge-robotic-surgery-gets-green-light-as-11-systems-are-recommended

[3] https://www.fortunebusinessinsights.com/industry-reports/surgical-robots-market-100948

Meanwhile, sterilization durability has become table stakes, where designs capable of surviving thousands of autoclave cycles without degradation are an attainable option for integrated motors, gearheads and feedback devices.

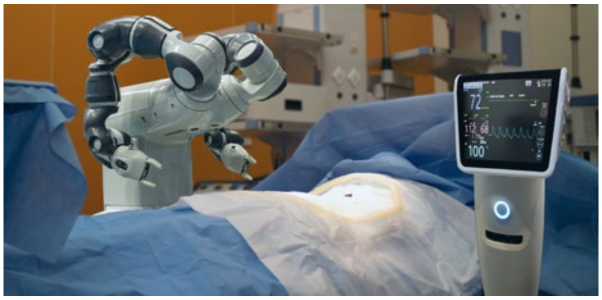
When these competing demands are not resolved early at the system level, they could impact development schedules and manifest as overheating, reliability issues, sterilization failures.

These trade-offs cannot be solved by swapping individual components. They must be addressed through motion architecture: the motor, geartrain, feedback system, and thermal strategy developed as a coordinated whole.

AI is Raising the Bar for Mechanical Performance

Surgical robotics aren't just getting smaller. They're also becoming smarter.

AI-driven systems are increasingly used to support navigation, enhance visualization, and assist with intraoperative decision-making. In some cases, platforms are moving toward semi-autonomous functions, relying on real-time data and predictive algorithms to guide surgical tools.



AI-enabled surgical systems rely on highly consistent, repeatable motion to execute commanded movements with predictability over time.

That puts new demands on the mechanics beneath the software. An AI-driven control system is only as reliable as the motion it commands, and it needs that motion to be consistent and repeatable over time – not just precise on day one.

As such, motion systems must now deliver not just precision, but predictability. Even small inconsistencies – torque ripple, cogging, thermal drift, or feedback noise – can degrade the performance of AI-driven control systems. Algorithms can compensate for many variables, but they can't overcome unstable physical behavior.

As a result, smooth motion, low vibration, stable thermal performance, and high-integrity feedback are no longer optimization targets; they're prerequisites.

From Components to Coordinated Systems

As robotic platforms grow more capable, they also grow more complex. In this environment, fragmentation across motion suppliers becomes a real liability rather than a minor inconvenience. Every additional interface introduces integration overhead, validation effort, and regulatory documentation burden. These costs compound quickly as systems scale.

In response, many OEMs are shifting away from treating motion as a collection of discrete components and toward designing it as a coordinated system. A single development organization may require a frameless motor integrated into a robotic joint for one platform, a compact sterilizable motor gearhead assembly for a handheld instrument on another, and a linear actuator for a third. When these needs are addressed within a shared motion architecture, OEMs gain consistency, reuse, and faster iteration across programs.

Just as importantly, system-level motion design enables clearer accountability. Fewer interfaces mean fewer failure points and less uncertainty when performance, reliability, or compliance issues arise.

An integrated motion subsystem combining motor, gearing, and feedback enables system-level performance, predictability, and simplified integration for surgical robotic platforms.

Supporting Innovation Through Collaboration

As the demands on motion systems intensify, early collaboration between OEMs and motion specialists becomes increasingly critical. Torque-speed load points, radial and axial loads, thermal envelopes, motion profiles, integration constraints – all of these are best addressed during concept development, when they're easier to define and validate than to correct later.

The same applies to the commercial trade-offs. Size, weight, power, and cost (SWaP-C) rarely align cleanly, and unresolved conflicts often reappear as late-stage redesigns or compromised performance. Early engineer-to-engineer engagement helps surface these tensions before they undermine timelines or manufacturability.

This collaborative approach also supports scalability. As surgical robotics adoption accelerates, suppliers must be able to support the full product lifecycle, from prototype through validation and into volume production – backed by the quality systems, manufacturing capacity, and global support required for regulated medical markets.

A Broader Motion Ecosystem for Surgical Robotics

This is where a system-oriented motion ecosystem becomes a meaningful differentiator. Regal Rexnord's portfolio spans precision motors, gearheads, linear motion systems, encoders, and integrated subsystems, enabling motion to be designed as a coherent whole rather than assembled from independent vendors.

Behind the portfolio sits a global manufacturing and support footprint, including 16 ISO-certified facilities and a worldwide presence capable of supporting the full product lifecycle. For OEMs, this translates into fewer supplier interfaces, clearer ownership of motion performance, and continuity from early development through production scale.

In a market where reliability, regulatory confidence, and speed to market are critical, that integration can significantly reduce risk.

Designing for What Comes Next

Surgical robotics has entered a new phase. Platforms are becoming more widespread, more specialized, and more intelligent. A new generation of surgeons trained on robotic techniques is now entering practice, while cost-effective platforms are expanding access beyond flagship hospitals. At the same time, systems are getting smaller, expectations for performance and reliability continue to rise, and total cost of ownership, ease of maintenance, and supply chain simplicity are no longer secondary considerations.

Through all of this, one thing remains constant: motion sits at the core of every robotic system. It determines how precisely a tool can move, how predictably it behaves over time, and how reliably it performs under real-world clinical demands.

The OEMs that will define the next generation of surgical robotics are the ones that treat motion as a system-level decision from the outset – designed for predictability, scalability, and the realities of modern healthcare.

Antonio Herrera
Senior Industry Manager
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About the Company

At Regal Rexnord, we create a better tomorrow with sustainable solutions that power, transmit, and control motion. Focused on customer needs and committed to sustainability, we harness innovation to transform industries and create a brighter future. From high-performance, precision motion control systems that power surgical robots, humanoids, satellites, and unmanned aerial vehicles, to advanced automation systems that optimize motion across factory floors, to precision-engineered power transmission components and innovative air moving solutions that drive efficiency, our technologies fuel progress.

The impact of Regal Rexnord's innovation capability goes far beyond our expertise and resources in surgical robotics. For more than 125 years, our portfolio of technology brands has grown intentionally and thoughtfully. We find the best and brightest ideas, bring them together under a single roof, build them to suit each customer's purpose, and create value far beyond their individual potential.

Utilizing our deep knowledge of the unique motion needs of the industries we serve -- robotics, aerospace, space, defense, medical, data centers, factory automation, renewable energy, agriculture, construction, and more -- we collaborate with our customers and serve as trusted advisors to deliver optimized solutions. Customer-focused innovation drives us, and our global network of design and manufacturing centers enables us to effectively engineer and reliably produce the complex solutions required to drive progress all around the world.

Headquartered in Milwaukee, Wisconsin, and with a worldwide presence of over 200 locations and 30,000 associated dedicated to customer success, Regal Rexnord (NYSE: RRX) empowers global industries to thrive sustainably while Creating a Better Tomorrow.

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