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IDC TECHNOLOGY SPOTLIGHT

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When the extensive capabilities of robotics are combined with human cognitive capacities, the future of work and operations blends into a new era of functional intelligence.

Robotics for Human Augmentation: Envisioning the Future of Work and Operations

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Introduction

Technology advancements are transforming the way we work. While many organizations are still considering their path for transformation, many have already started their adoption journey. They are finding increasing value in new, more efficient operational models that respond to unique situational constraints. To reach a high level of efficiency performance, organizations aspiring to become operationally intelligent not only must modernize operations but also must also apply such practices at scale.

The future state of operational excellence requires the combination of technology capabilities and the agility of people's cognitive skills. It requires organizations to rethink the notion of the operational environment entirely and envision a new level of technology/labor collaboration. Indeed, the operational environment transforms from rigid processes to constant unstructured orders.

AT A GLANCE

WHAT'S IMPORTANT

- IDC's vision for the future of work framework is about enabling and embracing the new digital worker. Exoskeleton technology can act as a catalyst to combine human cognitive skills and robotics performance, the new drivers of value for the future of work and operations.
- Innovation and agility are the two core capabilities that will determine the success of technology users in leveraging the benefits of applying a strategy toward their future of work and operations.

In that context, markets are entering the robotics-enabled human augmentation era. That is, organizational structures and metrics for success take into consideration the combination of technology and human capabilities: The expectation becomes net-new operational capabilities, not incremental adjustments. A relatively new category of robotics, exoskeletons — particularly the "powered" variety — augment human capabilities instead of replacing them. IDC believes that exoskeleton technology is a crucial enabler for the future of work and operations.

However, most organizations still operate in a status quo fashion that presents the following challenges:

- **Inflexible operations.** The operational environments constructed during the first 20 years of the 21st century lack the agility required to remain competitive for the next 20 years. Manual, repetitive operations limit scalability and growth. Monolithic, bloated, nonintegrated applications hinder effectiveness and demoralize workers. The sheer number of tools and data types required to complete a work process introduces excessive friction and context switching, further hampering speed and productivity and increasing worker disengagement. In a recent IDC survey covering the future

of work and operations, approximately one-third of respondents cited legacy infrastructure, inadequate integration, and governance concerns as barriers to modernizing operations and driving transformation initiatives.

- **Workforce limitations.** As the pace of technology advancement accelerates, the "half-life" of relevant and required skill sets declines. The growing need for new skills has also resulted in organizations leveraging disparate, ad hoc online training programs that limit the ability of organizations to monitor progress, adjust training priorities, and measure impact. Organizations that lack modern intelligent, agile, and adaptive training technologies supporting their operations will increasingly miss opportunities to align with increasingly unique customer requests.
- **Rigid organizations.** Traditional static, siloed organizational structures that are function focused rather than outcome focused tend to inhibit speed and agility and consequently prevent or greatly limit an organization's capacity to address unique requests and situations. Nonstandard operational constraints that are not otherwise complex can generate excessive levels of disruption across the board. Consequently, an organization's capacity to respond to trends is hindered in areas such as increasing value customization requirements and reaching the level of organizational flexibility that markets expect.

Rethinking the way work gets done is a fundamental shift in the work model to one that fosters human-machine collaboration, enables new skills and worker experiences, and supports an intelligent and dynamic environment unbounded by time or physical space. Operations transformation is critical for effectively scaling outcome-focused initiatives meant to boost business agility, worker productivity, and operational efficiency. These benefits drive more significant stakeholder engagement, innovation, and higher business value. As a result, organizations can establish competitive differentiation in a dynamic business environment.

Taking the First Practical Steps Toward the Future of Operations

Organizations rely on standardized automation to achieve operational excellence. Embracing the future of operations is an enterprisewide imperative. Achieving productivity growth, competitive differentiation, and new business value requires intimate collaboration among lines of business and technology leaders as well as HR and other departments.

Organizations should consider using a framework for scoping and defining their operations transformation strategy. They should start by answering the following questions:

- Does the organization have an enterprisewide strategy for operations transformation? Does it have senior-level support?
- Are specific strategies in place for work automation and augmentation? What is the role of the digital worker in the organization? Is the digital and augmented worker concept understood at the operations level? Has the organization established an automation center of excellence?
- Are the facilities keeping pace with a modern operations strategy?

Perhaps most important are questions related to the organization's ability to envision the regular use of otherwise nontraditional tools and equipment such as advanced robotics and exoskeletons. Usually, there are gaps between observing a new class of technology, considering its use locally and tactically, and executing its total integration at scale. Companies willing to create the framework for the integration of these highly flexible technologies will be able to address the challenges and requirements of infinitely unstructured operations.

Definitions: How Exoskeletons Fit into the Future of Work Framework

While part of the broader robotics and intelligent operational systems market segment, exoskeletons can be viewed as a distinct category of robotics that specifically enables human augmentation. Conceptually, these "augmentation robots" differ from the historical form factors associated with robotics, namely collaborative robots designed to automate production processes by replacing human workers with robotic counterparts.

The exoskeleton category represents various types of wearable robotic suits. There are generally two main types of exoskeletons: powered and passive. Each type comes in various form factors or body parts (i.e., lower, upper, or full body) and supports a different set of use cases and industry verticals. Powered exoskeletons help amplify or augment the user's physical attributes by combining human cognitive intelligence, instinct, and judgment with the strength and precision-enhancing capabilities of robotic systems. Passive exoskeletons are typically nonpowered, partial-body configurations designed to reduce physical strain from repetitive tasks by distributing force through the frame; they rely on springs, dampers, or other materials to store the transferred energy from human movement and release it mechanically, when required.

This paper focuses mainly on the powered, full-body exoskeleton category, with an emphasis on industrial use cases. At their core, these exoskeletons illustrate in-depth, combinatorial innovation requirements that include three key functionalities:

1. **Autonomous power and mobility.** Fitted with dedicated power management and usage, the full-body exoskeleton effectively bypasses the need for a wired power connection or "tether," which extends the system's mobility, versatility, and applicability to a variety of use cases as well as future unique situations.
2. **Superior maneuverability and dexterity.** Powered, full-body exoskeletons are ideal for tasks in both structured and unstructured environments. By integrating the ability to move as a human would — through advanced kinematics, integrated sensors, and multiple degrees of freedom — exoskeletons allow operators to intuitively control the robot and achieve maximum maneuverability and dexterity. These exoskeletons also present unique productivity-enhancing capabilities that would typically require multiple workers to complete, such as lifting a heavy payload while allowing operators to use their own hands to fine-tune adjustments or complete precision tasks.
3. **Endurance.** Full-body, powered exoskeletons amplify a human's strength, enabling the operator to handle physically demanding tasks for longer periods, without adding strain or increasing risk of injury.

The full-body, powered exoskeleton subsegment has seen significant advancements recently in system capability, packaging, and commercial viability. The ability of the exoskeleton to support the entire weight of the suit and the item being lifted while carrying up to 200 pounds addresses a wide range of applications in industrial, military, and consumer verticals.

Benefits

In most cases, organizations adopt robotic solutions as part of their "business process modeling" to bring incremental efficiencies to existing methods and processes. Optimizing existing processes and operations, however, is not real innovation. Innovating means addressing new use cases. Innovation requires rethinking processes and creating new processes, not merely changing old processes. Innovation applied to the operational environment translates into a case of "business process architecture," which relates to the activity of creating new methods for an enterprise to deliver novel, higher-value outcomes. For most operations-intensive sectors, it implies reviewing and creating a different usage model for technologies such as robotics and exoskeletons. Such use cases must also deliver combinatorial value (i.e., processes that enhance productivity while enabling greater flexibility, worker safety, and affordability).

Exoskeletons are not only "enablement" equipment. They open up an entirely new era, the robotics augmentation era, where individuals remain in the value chain and participate in it by doing more and for longer, further removing several societal hurdles new robotic solutions face. In theory, robotics augmentation allows a plug-and-play usage model for which no specialized skills are required. That would virtually scrap implementation and deployment time/costs/complexity, on top of changing the need for side technologies such as vision systems, elaborate artificial intelligence, and so on. Robotics augmentation is already occurring in the form of exoskeleton solutions, most notably for healthcare and military use cases (e.g., injury recovery).

Exoskeleton technology is not just futuristic speculation. Indeed, exoskeletons are being deployed in industries that are more reliant on extending physical abilities in unstructured environments. This technology will help organizations overcome critical business challenges, such as meeting market demand for maximum operational capacity.

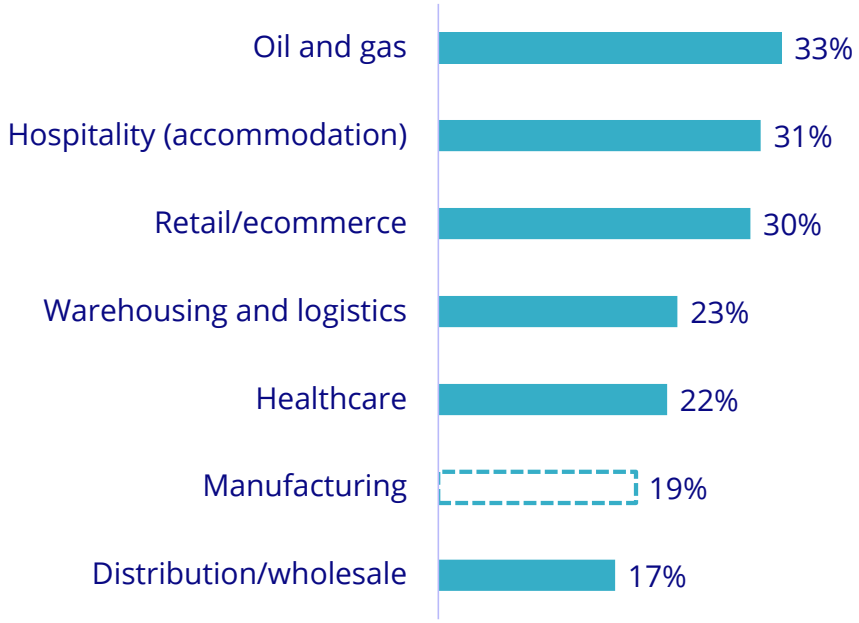
Key Trends

The Market Is Broadly Considering Exoskeleton Technology

Exoskeletons are being deployed gradually, and the market is anticipating rapid and further development of the technology. Interest is coming from technology users across a vast array of sectors (see Figure 1), as many enterprises now understand the applicability of exoskeletons, especially when it comes to simplicity in deployment and tangible, measurable outcomes.

FIGURE 1: ***Interest in Exoskeleton Technology in North America by Sector***

Q *What types of robots are you researching, piloting, using, or planning to deploy within your organization? (A: Exoskeleton)*



n = 452 respondents currently deploying/piloting/planning to deploy/researching and considering exoskeletons at their organization

Note: The manufacturing ratio is projected from IDC's North America Industrial Robotics Survey, August 2019

Source: IDC's North America Commercial Service Robotics Survey, August 2019 and IDC's North America Industrial Robotics Survey, August 2019

While the manufacturing sector is being accounted for in the previously mentioned survey results only as a projection based on separate IDC survey results (IDC's *North America Industrial Robotics Survey, 2019*), it is also likely to adopt exoskeleton technologies in the near term. IDC expects deployments to fall somewhere between the warehousing and logistics sector and the distribution/wholesale sector.

It is essential to consider the results presented in Figure 1 relative to the current maturity of each sector as it relates to robotics adoption at large. It means fully understanding the current operational process and determining what level of automation is needed. In some cases, automation can add complexity, and its limitations in unstructured environments can hinder an enterprise's ability to be agile. In such situations, the versatility and robustness of exoskeletons could prove a solution and therefore drive new innovative use of robotics by vertical sectors and use cases (i.e., develop use cases too complex to be addressed by non-exoskeleton robotics).

For example, respondents from the hospitality sector seem keen to explore the use of exoskeleton technology. Yet the same industry can't be broadly considered as mature as the warehousing and logistics sector in a technology adoption cycle. On the contrary, the oil and gas industry, with 33% of respondents indicating interest, could prove a significant active exoskeleton market in the years to come. Indeed, the oil and gas sector has had more experience evaluating and deploying robotics than other industry sectors. Despite the complexity of several sector-centric use cases, oil and gas is projected to spend over $140 million on robotic systems in North America through 2020 (source: IDC's *Worldwide Semiannual Robotics and Drones Spending Guide, 1H19,* October 2019).

Adoption Drivers

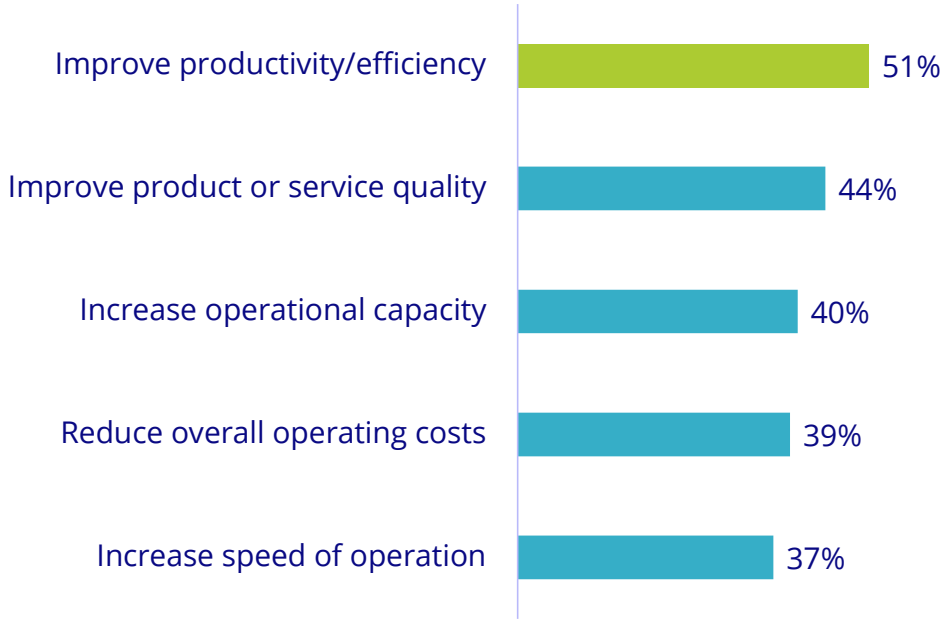
Robotics, including service robotics, is primarily adopted by companies to respond to standard back-office challenges. Expectedly, surveyed users lean toward the usual, yet critical, operational mandates (see Figure 2). Such drivers tend to direct providers to design solutions around generic use cases, responding to immediate constraints at the local level. While executive management and line-of-business leaders are increasing their robotics fluency, most existing users sit within operational functions and target the improvement of standard operational key performance indicators (KPIs).

Figure 2 presents top drivers leading nonmanufacturing organizations to deploy robotics technology. Although results are generally consistent across sectors, a noticeable exception is the oil and gas industry, which, unlike all other sectors, positions "improve worker safety" as the top driver for robotics deployment (46% of respondents), followed by "increase operational capacity" (42% of respondents) and "improve product or service quality" (41% of respondents). All other drivers scored below the 38% mark. The uniqueness of oil and gas use cases is thought to be the primary reason for the deviations seen from this sector. Often core operations are undertaken in remote locations with limited resources as well as constraints including topography, tight geometries, and rough climates. The operational field environment can be dangerous, and in this context, intelligent automation unsurprisingly mitigates physical risks to workers.

FIGURE 2: ***Main Drivers for Deployment of Robotics in North America***

Nonmanufacturing Sectors Only

Q *Please rank the top 5 drivers for deploying robots in your organization.*



n = 452 respondents currently deploying/piloting/planning to deploy/researching and considering service robotic at their organization

Note: Multiple responses were allowed.

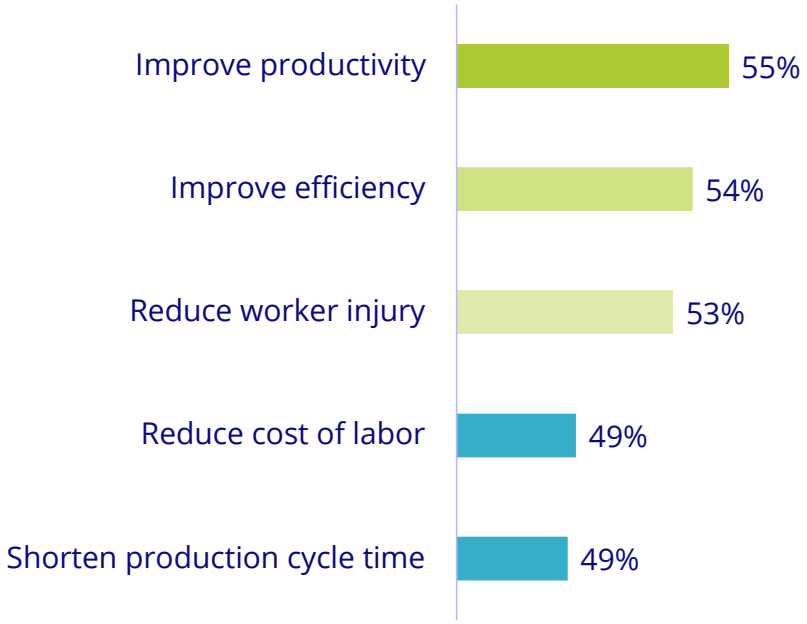
Source: IDC's North America Commercial Service Robotics Survey, August 2019

For manufacturing industries (see Figure 3), improving productivity and improving efficiency are the primary drivers for the adoption of robotic technologies. However, the reduction of injuries to staff (ranked third) corresponds well with exoskeleton capabilities. Manufacturers have historically been early adopters of robotics and traditionally deployed the technology within "caged" environments (i.e., not physically accessible by people, in cells), which explains manufacturers' more mature approach and a high adoption rate with the new generation of robotics. Recent examples such as the rapid adoption of collaborative robot arm technology (i.e., machines not requiring a closed environment to operate and adjust to the proximity of people) are encouraging for future adoption of exoskeletons.

FIGURE 3: ***Main Drivers for Deployment of Robotics in North America***

Manufacturing Sectors Only

Q *Please rank the top 5 drivers for deploying robots in your organization.*



n = 602

Note: Multiple responses were allowed.

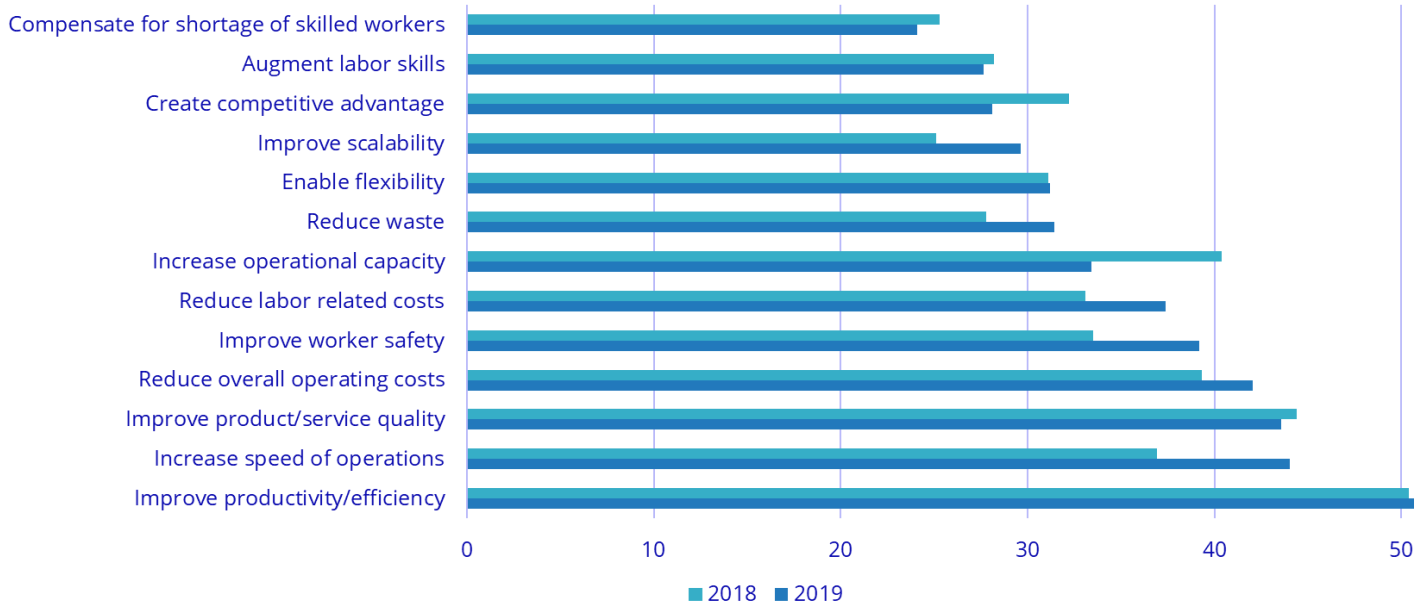
Source: IDC's North America Industrial Robotics Survey, August 2019

In conducting a year-on-year comparison of the reasons that nonmanufacturing companies are deploying robotic solutions, IDC identified productivity/efficiency, speed of operations, and quality as the top 3 drivers overall in the industries surveyed (see Figure 4). Increasing the speed of operations is gaining traction as a driver, while increasing operational capacity is dropping in the priority stack.

FIGURE 4: ***Reasons for Deploying Robotics in North America: Year-on-Year Comparison***

Nonmanufacturing Sectors Only

Q *What are the top 5 reasons for deploying robots in your organization?*



n = 181 respondents currently deploying/piloting service robotics at their organization

Note: Multiple responses were allowed.

Source: IDC's Commercial Service Robotics Survey, August 2019 and IDC's Commercial Service Robotics Survey, July 2018

The relative maturity among robotics users in the manufacturing sector of North America is illustrated by how robust the percentages of the top 5 drivers for deployment are on a broad list of possibilities.

Figure 5 captures outcomes experienced by manufacturers in post-deployment or post-pilot phases of robotics technology. A whopping 72% of respondents indicated improvement in quality and repeatability, while a remarkable 66% of respondents noticed a reduction in worker injury accidents. These net positive results, especially if they align with initial goals, are critical indicators. Indeed, they demonstrate the value of a class of technology that can still be considered innovation experimentation. For the adoption cycle of a new subclass of robotics such as exoskeleton technology, users would generally be more willing to discuss and pilot associated projects.

FIGURE 5: ***Robotics Post-Deployment Outcomes in North America***

Manufacturing Sectors Only

Q ***Please rank the top 5 benefits achieved by the deployment of robotics in your organization.***

n = 602

Base = user/intender/explorer respondents

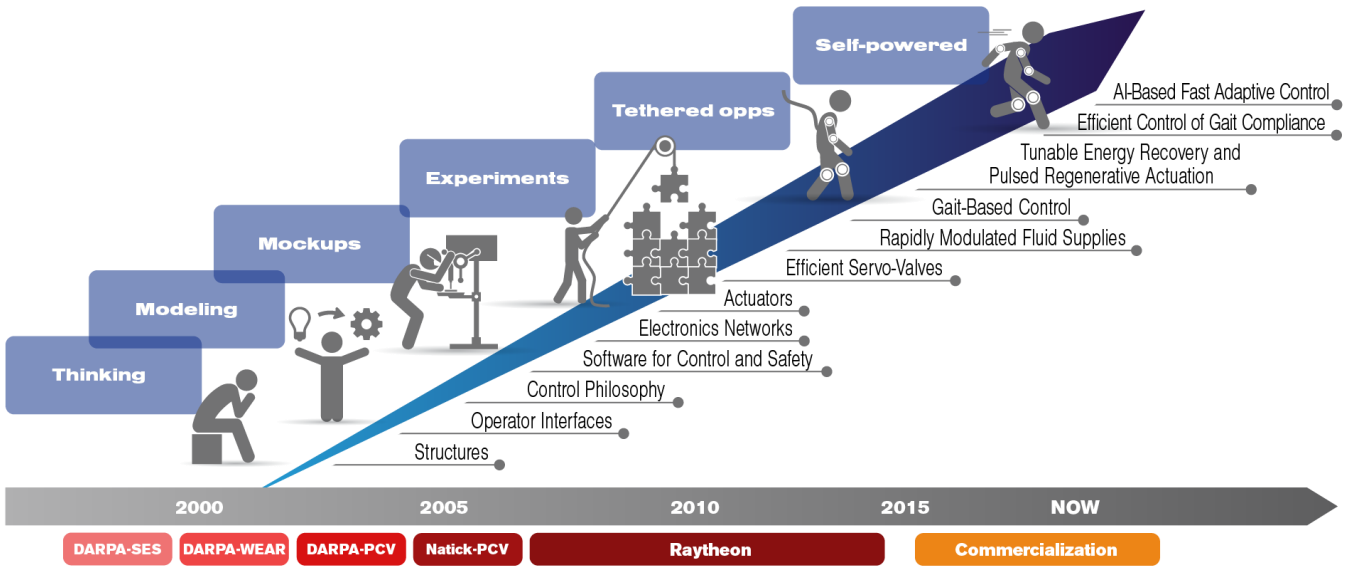
Note: Multiple responses were allowed.

Source: IDC's North America Industrial Robotics Survey, August 2019

Considering Sarcos Robotics

Sarcos Robotics is a global leader in humanoid robots, human-machine interfaces, and industrial-powered exoskeletons. Headquartered in Utah and founded in 1983, the company initially developed with a focus on actuated prosthetics. From 2007 until 2014, Sarcos Robotics operated as the robotics division of Raytheon. As of December 2019, the company employs over 140 staff and has issued over 140 patents. Sarcos exoskeleton technology has been in development since 2000 (see Figure 6). It evolved from a concept to a model and then to different versions of the exoskeleton, including a tethered version followed by the most recent battery-powered version, which was launched in November 2019.

FIGURE 6: ***Sarcos Robotics' Powered Exoskeleton Development***



Source: Sarcos Robotics, 2020

Guardian XO

Most recently, Sarcos Robotics introduced a new commercial iteration, the Guardian XO industrial exoskeleton. The Sarcos Guardian XO robot promises to augment the user's strength and endurance, reduce injuries, and generally enhance productivity.

Main Features

- Ability to lift up to 200 pounds (90 kilograms)
- Near-continuous runtime via three hot-swappable batteries
- 100% load relief (supports the weight of the suit and the payload)
- Takes less than 30 seconds for the user to don/doff the suit

Main Benefits

The Guardian XO exoskeleton is capable of boosting an individual employee's productivity by a factor of 4 to 10 while dramatically reducing costly occupational injuries. The principal factor is that the solution transforms the way work gets done by augmenting operator strength and endurance without restricting freedom of movement or adding fatigue and strain.

Guardian XO in Context

- **Power requirement.** The solution consumes about the same amount of power as the average television and less power than the average refrigerator or coffee maker.
- **Torque.** The peak torque of the Guardian XO exoskeleton is about 4,000 inch-pounds, which is about twice as much as the peak torque of a regular sedan car (U.S. standards).
- **Range of movement.** The Guardian XO exoskeleton permits 24 degrees of freedom, while a basic backhoe (farm equipment) has only 4 degrees of freedom.
- **Processing power.** The exoskeleton integrates roughly the same computing power as three PC servers.
- **Sensors to eliminate latency.** The equipment's operator input (load cells) can sense weights ranging from the equivalent of a third of a chocolate bar to three motorcycles; it detects operator movements within milliseconds.

Challenges

While exoskeletons will play an increasingly critical role in supporting work and transforming operations, the following challenges must be addressed for successful deployments:

- **An efficient, scalable, and adaptable digital workforce** that can be deployed to automate and augment a variety of operational work activities in the physical world
- **Collaborative tools** that enable better information exchange at the operational level by including new capabilities delivered thanks to "operationally augmented human workers" within a broader and digitized operational systems strategy
- **Integrated workplace sensing systems** that optimize and personalize the employee experience and enhance productivity, safety, and security

Conclusion

IDC's vision for the future of work framework is about enabling and embracing the new digital worker (i.e., technologies such as artificial intelligence and robotics). These opportunities include full automation as well as augmentation and encompass both information work and operational work. Though some jobs will be completely automated, the reality is that these technologies will most frequently augment, rather than fully replace, activities performed by human workers. Solutions that will successfully scale across an organization will be those that not only enable workers to be more productive but also allow them the freedom to focus on higher-value activities and innovation, ultimately driving improved worker experiences and new value for the organization.

That is why IDC believes the exoskeleton market will continue to grow rapidly and eventually experience exponential demand throughout operations-intensive sectors. To the extent that Sarcos can address the challenges described in this paper, the company has a significant opportunity for ongoing success.

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About the Analyst

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Jonathan Lang is Research Manager for IDC Manufacturing Insights responsible for the IT/OT Convergence Strategies practice. Mr. Lang's research focuses on digital transformation strategies in environments where operations technologies are deployed including Manufacturing, Utilities, Oil & Gas and Healthcare Provider settings. As IT capabilities redefine and extend the core value drivers of operations technologies, Mr. Lang's research examines strategies, roadmaps, and governance models to drive this convergence and manage the new data and processes it requires.

MESSAGE FROM THE SPONSOR

The Guardian XO full-body powered exoskeleton is the world's first battery-powered industrial robot to combine human intelligence, instinct, and judgment with the power, endurance, and precision of machines. Set to transform the way work gets done, the Guardian XO augments operator strength without restricting freedom of movement to boost productivity and dramatically reduce injuries. Commercially available at the end of 2020 in a wide variety of industries including industrial manufacturing, automotive, aviation & aerospace, oil & gas, construction, maritime, and distribution & warehousing. Please visit ***www.sarcos.com*** to schedule a consultation on how the Guardian XO can transform your workplace safety and efficiency.

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