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This annual research report seeks to highlight the technological breakthroughs evolving today and creating the potential for super-exponential growth tomorrow.
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Hi everyone, I'm Sam Corris, Director of Research for Autonomous Technology and Robotics at ARC.
And today I'm joined by Tasha Keeney.
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I direct investment analysis and institutional strategies for ARC.
And today we're diving into big ideas and talking about robotics and 3D printing.
Both of these combined, really changing the way that manufacturing is done.
Now when we're talking about innovation, there are always risks to this.
There's the rapid pace of change.
There's the ever-evolving competitive landscape.
There's different regulatory hurdles that come into this, as well as political and legal changes that have to adapt to all of these new technologies at once.
So there are risks involved, but it's super exciting and we're going to dive into it.
Robotics and 3D printing are collapsing the time from development to production.
They're changing the way supply chains are aligned, reducing waste, lowering costs, and all in ARC estimates that manufacturing robots and 3D printing could scale at an 80% annual growth rate during the next eight years from roughly $70 billion in 2022 to $9 trillion by 2030.
And so what we see with the adoption of automation is that it actually accelerates during recessions and crises.
And what we're looking at here is the chart of industrial robots and the demonstration of price elasticity of demand, but also highlighting those times of turmoil when new technologies come in and help solve those problems.
And so the first point here where we see this is after the dot-com bust in 2002, and you see a slight uptick in the rate of robotic adoption, then you have the 0809 crisis, and that's when you really get a new wave of adoption for collaborative industrial robots.

And then again, what we just saw most recently was a little bit of a slowdown due to the China-US trade conflict in 2019, and then those supply chain bottlenecks during COVID from 2020 through the following year.
What we actually saw is that in 2021, you actually had what we expected, and you had this bounce back in robotic adoption, and we think this will carry on for 2022 and 2023.
And what I think is incredible, not just these cost declines when it comes to robotics, but the performance as well.
So one of the key tasks that people point to when they're looking at robots and how they can be used in manufacturing is picking place.
So taking something from maybe a bin, putting it onto a conveyor belt, or maybe taking it from a conveyor belt and putting it into a box.
And when you look at this chart, you can see in 2015, this was the first Amazon robot picking and placing challenge, and it was a pretty poor performance when it comes to robot picking and placing, but obviously amazing at that time.
And you can see for context, humans can pick and place roughly 400 items per hour.
And with advances in computer vision and deep learning, from 2015 to 2022, there's been a 33-fold increase in performance.
And so you can see now robots are clearly outperforming humans, and there's no reason why this should slow down.
Continuing on with Amazon, you can see that they're really leaning into the robot deployment, and it would not surprise us if within the next few years, Amazon were to add more robots than humans to its employee workforce.
And we've heard last year that Amazon's producing or has the capability to produce 1,000 robots per day.
So that's pretty remarkable when you think about scaling, manufacturing, scaling warehouses, and the level of automation that you can get to.
And so that raises the question, what is the ultimate level of robot penetration in manufacturing?
And you can look and you can see that Amazon has 3,200 robots per 10,000 employees.
You can compare that to the auto industry, which only has 1,300 robots per 10,000 employees.
And then if you look at manufacturing overall, there's this huge opportunity to increase the robot density, just 140 robots per 10,000 employees.
And so if you were to take the manufacturing industry as a whole and just get it to where Amazon is in 2022, you'd have to add 4 million robots.
So that's roughly six times the unit sales of industrial robots globally today.
But there's nothing to say that Amazon's reached full robot penetration.
And in fact, we don't think that 3,200 is this upper limit.
And it's unclear where this upper limit is.
You can almost certainly have more robots than humans working in an environment.
And so we really think we're just at the beginning of the level of penetration we can have for robots in manufacturing.
Now I'm going to pass it to Tasha to talk about how 3D printing can impact all of these different industries.
Thanks, Sam.
So onto a different type of robot, a 3D printer.

3D printers build parts in a layer by layer process.
Here we're talking about both metal and plastics and all the different types of 3D printers you see out there from the extrusion based machines to the lasers to the light curing machines.
Ultimately, we see a $500 billion market opportunity for 3D printing across a variety of industries.
So if you look at the graph here, I'd say two industries I'd like to point out as critical are healthcare and aerospace.
These in particular tend to have lower volume, highly complex parts, which are very amenable to 3D printing.
Often you can combine multiple parts into a single part, which can save you on strength.
It can also improve the weight of the part, which is great for aerospace.
You can reduce the amount of fuel needed in many applications.
And also you'll see here the automotive and machinery categories.
All these tend to contain higher volume parts, and you may not initially think about them for 3D printing.
They actually end up being very critical because the industries are so large that 3D printing, even penetrating a small portion of them, could be very significant to the 3D printing industry overall.
But I'll add that these are applications that we see today.
It's likely that 3D printing is going to introduce many applications that we can't even foresee.
So this is a great example.
3D printing was used for the Boston Dynamics humanoid robot.
It gave the robot the correct strength to weight ratio that allowed it to take these nice leaps here that you see in the chart and some results, thanks to 3D printing.
So again, this is something that wasn't possible without this technology.
We often get asked, okay, why hasn't 3D printing grown as quickly as, let's say, some analysts might expect?
Well, if you look at survey data, so this is data that's compiled over a four-year period here, often companies and representatives inside those companies are saying that materials, costs, know-how, and design or process issues are barriers to adopting 3D printing.
A couple things that I'll point out is, for 3D printing, costs should really be compared over the lifetime of the part from design all the way to retirement or replacement of that part, because often 3D printing, well, sometimes 3D printing could be more expensive at the upfront, but it actually creates more durable parts.
So you need to replace them less and you can shorten the time from design to production.
So it's really, it needs to be measured over a full life cycle, which can sometimes be difficult to do.
For personnel, 3D printing, it's no longer a new industry.
It's been around for the past decade, but most of the most qualified people are right now just, they're the young engineers, they're coming out of school, they're the ones that were directly trained while they were getting their engineering degrees in things like 3D printing.
And then design or process, to really get the full benefits of 3D printing, you need to design from the ground up.
It might not just be directly replacing a part identical to what it used to look like in manufacturing, but you might combine multiple parts into one.
So really starting from scratch, you get the best benefits here.

And the other thing that I'd say is that the chart here on the left,
over the past four years, we've seen a significant uptake in companies that are using 3D printing for jigs and fixtures, bridge production, which is, you might be in a pinch and need to produce parts quickly, you're going to turn to 3D printing versus let's say tool up a traditional manufacturing machine that might take weeks or months to get up to scale and get going.
And then production parts, this is the most critical category.
We think that's the largest bucket for 3D printing addressable market.
So it's really good to see additional uptake there.
And to talk about a couple applications, in healthcare, 3D printing can make a big difference.
So these are tools, guides, and models that are used ahead of the surgery and in the surgery.
These applications can reduce the average operating time by about 30% if you look at studies.
And the performance or the surgical accuracy and results that you get coming out of the surgery can be approved by 40 to 50%.
That's really amazing.
So that's a better outcome for the patient, but also the doctors.
And ultimately, you can imagine that you could get more throughput in operating rooms.
So we think that all in all, the time spent in US operating rooms for all surgery types could fall by 5%, and that would save about $12.5 billion.
If you scaled that up to a global estimate, that would be roughly $80 billion,
just saved on cutting down the surgery time alone.
And this is really important because right now, globally, there's roughly 140 million cases a year as of the last estimate that are not able to be addressed by surgery.
So increasing that throughput could be one of the variables that helps address those additional cases. Another application I'd like to talk about is AI and 3D printing.
This is really a perfect marriage here of the convergence that we always talk about here at ARC. So in using machine learning algorithms, researchers are able to reduce print error by roughly 30%. And they actually found that products were two times as strong and waste of materials was reduced by up to 40%. So AI can produce high, more accurate parts that have better finish.
That's the print error side of things. You might need to, you might not need as much post-processing, and there could be fewer defects as well.
This is a critical tool for companies that have very strict standards in manufacturing where you need to make the same exact part over and over again in a highly repeatable process.
And I'll note that we think that companies that are best positioned to take advantage of this opportunity are the ones that own the full software stack. So you build the printers,
you have a sensor set that gathers data on each print, and then you're able to use that information to enable over-the-air software updates so that the printer actually gets better with time. So controlling that ecosystem really matters here. All in all, we expect the enterprise value for robotics and 3D printing to scale 80%, as Sam mentioned, at an annual rate during the next eight years from roughly $70 billion today to more than $9 trillion in 2030. As you can see here, the vast majority of that is robotics. 3D printing is roughly 700 billion robotics,
about 8.4 trillion expected value in 2030. So this is a massive opportunity that we're very excited for.
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